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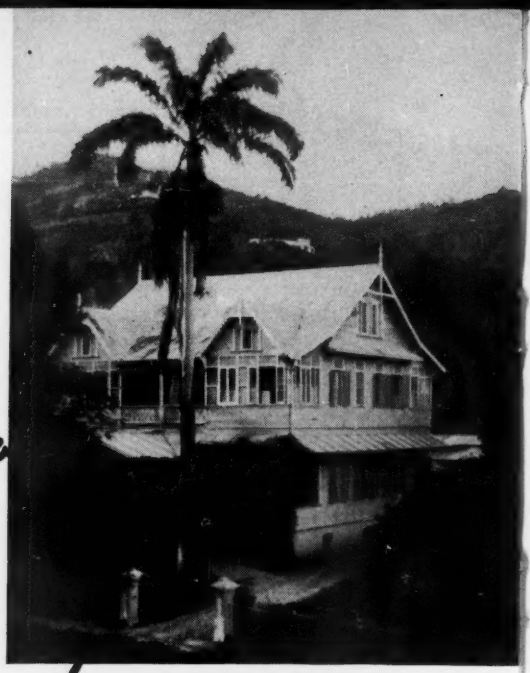

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SUBSURFACE GEOLOGY OF CHESTER SERIES IN ILLINOIS[1]

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ABSTRACT

The Chester series underlies most of the southern half of Illinois east of East St. Louis. Except where they have been removed by post-Chester erosion, all of the formations in the standard Chester section can be identified in the area. Producing formations are the Cypress and Bethel sandstones, both of which are in the lower part of the Chester series. The maximum known thickness is 1,450 feet at a point in the most southerly part of the area. Because of northward thinning of individual formations, the original thickness of the entire section in the northern part of the area was probably half of this. Uplift, warping, and peneplanation previous to the deposition of Pennsylvanian sediments caused truncation of the series throughout the basin and scalping of local structures. The isopach map indicates two major pre-Pennsylvanian anticlinal areas in which are located a large proportion of the Illinois oil fields, one the LaSalle anticline, and the other an uplift extending southeast from the region of Sorento.

INTRODUCTION

The Chester series occupies an area in the southern half of Illinois known as the Illinois basin. All the formations of the standard Chester section are present in the basin and have formerly had a much wider extent than at present. They are essentially parallel with no great unconformities separating them and are likewise essentially parallel with the underlying formations of the Iowa series of the Mississippian system. However, they were warped, tilted southward, and truncated previous to the deposition of Pennsylvanian strata, causing the pattern of formations shown in the accompanying areal geologic map of the Chester series below the Pennsylvanian system (Fig. 1). The stratigraphic relations of the Chester formations are shown in the geologic cross sections (Fig. 2).

[1] Read before the Association at Oklahoma City, March 24, 1939. Manuscript received, August 6, 1939. Published with the permission of M. M. Leighton, Chief, Illinois State Geological Survey.

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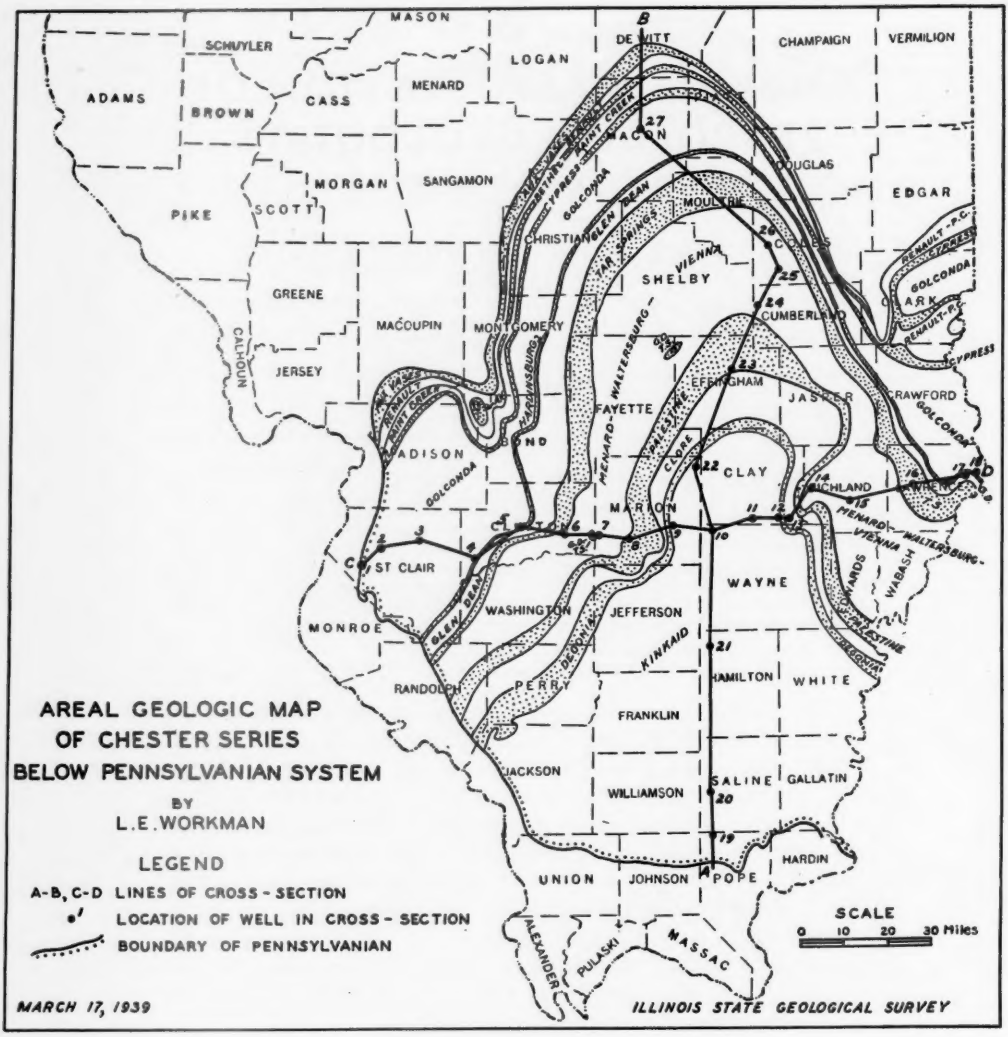


FIG. 1.—Areal geologic map of Chester series below Pennsylvanian system.

Kinkaid formation.—The Kinkaid formation is the topmost formation of the Chester series. In the Illinois basin it consists mostly of limestones and interbedded shales, but there are also some sandstone, siltstone, and chert beds. In a well in northern Pope County, in the southern part of the basin, the formation reaches its thickest development and is described as follows.

Description of Strata	*Thickness in Feet*
Limestone, mottled, very fine- to coarse-grained; some shale, dark gray	60
Shale, green and red; limestone, red and brown	15
Limestone, argillaceous, very fine-grained; shale, partly silty, gray	40
Shale, silty, grading to siltstone and sandstone	20
Limestone, argillaceous, mottled to dense, in places cherty, very fine- to coarse-grained; shale, gray to black	35
Shale, silty, dark gray to red and green; some limestone beds	15
Total	185

The limestones are more or less cherty, being especially cherty where they lie close under the Pennsylvanian strata. The strata extend laterally without important variations. The lowest limestone zone is the one encountered directly under the Pennsylvanian strata in drilling at most locations in Wayne and eastern Marion counties.

The Kinkaid formation thins northward under the erosional unconformity at the base of the Pennsylvanian system.

Degonia sandstone.—In areas of its thicker development, the Degonia sandstone is calcareous, very fine- to medium-grained, and white to light green and gray in color. As the formation becomes thinner laterally it becomes finer-grained, silty, and argillaceous and grades to carbonaceous, dark gray shale. In places it has a quartzitic appearance due to the cementing of the sand grains by silica.

The Degonia sandstone is 100–125 feet thick in Jackson County which is in the southwestern part of its area of occurrence in the Illinois basin. It thins eastward to about 50 feet in White County and northeastward to about 25 feet in northeastern Marion County.

Clore formation.—The Clore formation is variable in character. It consists of beds of buff to dark brownish gray, lithographic to coarse-grained, more or less argillaceous limestone alternating with red and green to dark gray shales, and contains also some sandstone beds. Chert, sand, oölites, and dolomite occur irregularly in the limestones. The lower limestones are more dolomitic than the upper, grading in places to dolomite.

The Clore formation ranges irregularly from 50 to 100 feet in thickness, becoming thicker toward the south.

Palestine sandstone.—The Palestine sandstone is generally calcareous, light gray to white, and very fine- to fine-grained. It contains

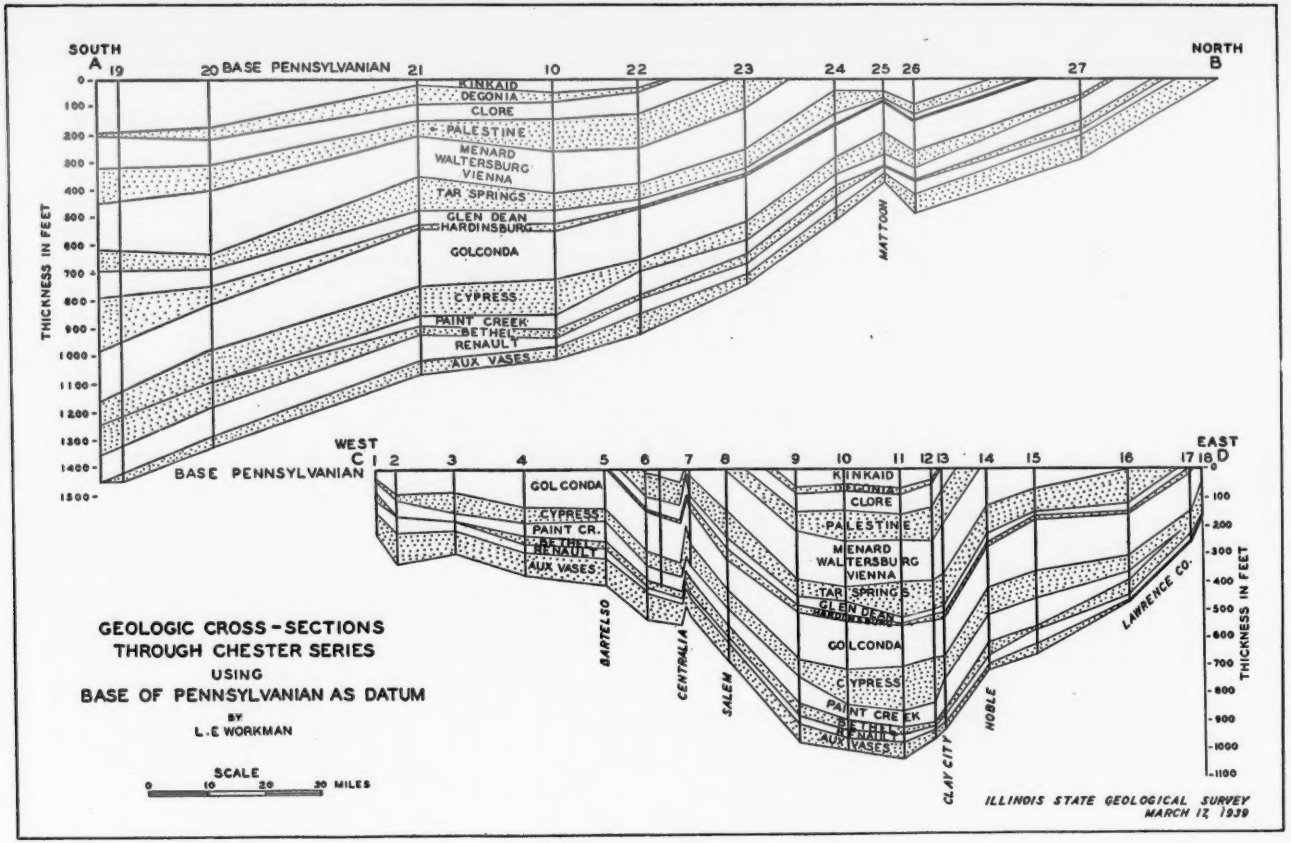


FIG. 2.—Geologic cross sections through Chester series on base of Pennsylvanian system as datum.

dark gray, carbonaceous, silty partings and some interbedded dark gray, silty to sandy, carbonaceous shale. The contact with the overlying Clore is in some places difficult to distinguish because of the presence in both formations of this type of dark carbonaceous shale.

The sandstone averages 40 feet in thickness in the western part of the Illinois basin, in Washington and Jackson counties, and it thickens eastward to 100 and 120 feet in the eastern part. Unlike most of the other Chester formations, the Palestine sandstone does not thin northward, being nearly as thick in Effingham County as in Gallatin County.

Menard formation.—The Menard formation is best developed in the southwestern part of the basin, in Jackson, Randolph, and Perry counties, where it may be divided into five zones: three zones of shale at the top, middle, and bottom with two alternating zones of limestone. These divisions of the Menard, however, may be observed elsewhere throughout its area in the basin. The limestone zones are 20–50 feet thick. The limestones are buff to brown and dark brownish gray, more or less argillaceous, and very fine- to coarse-grained in texture. Partly oölitic, speckled, light to dark gray and brownish limestone, similar to limestones of the Glen Dean and upper Golconda formations, are present in the Menard. Chert is irregularly present. The lower limestone zone is characterized by dolomitic limestone and a few beds of true dolomite. Some shale is interbedded with the limestone, and here and there, especially in the lower limestone zone, increases in proportion so as to constitute a considerable part of the zone. The three shale zones consist mostly of brown to dark gray calcareous shale but contain also some interbedded limestone. Red and green shales occur sporadically in each of the three zones.

The Menard formation is 125 to 135 feet thick in the southern part of its area, in Jackson to Pope counties, and thins northward to 70 or 80 feet.

Waltersburg sandstone.—The Waltersburg formation is best developed in the eastern part of the basin from Wabash to Pope counties where it consists of light greenish gray to white, very fine- to fine-grained sandstone. Westward it is more shaly, grading to greenish to gray shaly sandstone and siltstone, and in many places appearing quartzitic.

In the southeastern part of the basin the Waltersburg formation is 35–50 feet thick. It thins northwestward to 10 feet or less, and in places it is difficult to identify it in the well cuttings.

Vienna formation.—The Vienna formation is variable in character. In its typical development it consists of dark brown to brownish

gray limestone which is more common near the top of the formation, grading to a predominance of shale at the base. The limestone grades in texture from lithographic to coarsely crinoidal, is ordinarily dolomitic, and is commonly siliceous to cherty. Most of the shales are brown and dark gray to black, but red and green shales are present. The darker shales commonly contain siderite concretions and are more or less silty and carbonaceous. The more calcareous phases of the Vienna are in the south, but northward the formation becomes silty and sandy and some thin sandstones occur. A sandy limestone is common in the base of the formation in Marion and Fayette counties.

The Vienna formation ranges irregularly in thickness from 40 to 80 feet. It is thinnest in the southwest in western Jackson County where it is only 15 feet thick.

Tar Springs sandstone.—The Tar Springs is white to light gray, very fine- to fine-grained, calcareous sandstone. It contains carbonaceous material on bedding and laminae surfaces. In places the grains reach medium sizes. In the southeastern part of its area, from Williamson and Pope to Richland and Edwards counties, and also in scattered occurrences elsewhere, the Tar Springs is made up of three zones consisting of an upper and lower sandstone zone and a middle shaly zone containing dark gray, sandy, carbonaceous shale. In a few wells in Williamson, Pope, and Edwards counties this zone contains a thin coal overlain by green, smooth shale.

The Tar Springs ranges in thickness from 60 to 100 feet in most of its area of occurrence in Illinois. It is thinnest in the area extending west from Clinton to northwest Jackson County where it is only 40–30 feet thick. Along the eastern border from Cumberland to Gallatin counties it averages 100 feet in thickness.

Glen Dean formation.—A number of wells in Jackson and Randolph counties, where the Glen Dean formation is developed to its greatest thickness, show the following succession of strata in the formation.

	Thickness in Feet
Shale, red, green, and gray, partly calcareous, silty to smooth; a few limestone lenses	5–25
Limestone, slightly cherty, oölitic, light brown and gray speckled, coarse-grained, fossiliferous	30
Shale, calcareous, gray	0–10
Limestone, argillaceous, partly oölitic, speckled, coarse-grained	25
Limestone, cherty, speckled, coarse-grained	10
Shale, red and green, smooth	5

These various members have not yet been traced eastward in the

Illinois basin but the general characters of the formation remain the same. The formation is typically coarse-grained, crinoidal, oölitic, speckled brownish gray limestone containing variable amounts of chert and dolomite. There is a minor amount of interbedded calcareous and dolomitic dark gray shale, although in a few localities the limestone content decreases so as to be only a minor proportion or even disappears. Red and green shales are rare in the Glen Dean, and where found occur only at the top or bottom, more commonly at the bottom.

The Glen Dean formation is 80–90 feet thick along the southwestern and southern border of its area in Illinois. In an area extending northward from Johnson County through the center of Williamson, Franklin, and Jefferson counties it thins northward from about 90 feet to only 70 feet. On the west and east in the same latitude it is about 65–40 feet thick. This area of thick Glen Dean is just east of the Du Quoin anticline and may indicate some differential anticlinal and synclinal movement during the deposition of the Glen Dean sediments.

Hardinsburg sandstone.—The Hardinsburg sandstone in its areas of thicker development is calcareous, white to gray, very fine- to fine-grained, and friable. Where it is thin it is ordinarily calcareous, more or less argillaceous, light to medium gray and green, compact, and grades to green and gray siltstone, in many places appearing quartzitic.

The Hardinsburg is thickest in Johnson, Pope, and Hardin counties where it is generally more than 100 feet thick and reaches a known thickness of 170 feet in northern Pope County. It thins in a short distance northward to 60 or 65 feet in southern Williamson, Saline, and Gallatin counties. In a wide area north of this and southeast of a line extending from Lawrence County to the middle of Jackson County, it is about 60 feet thick. Northwest of this line the formation is generally 30 feet or less in thickness and it thins and almost disappears in the vicinity of its present northwest, north, and northeast borders. In a local area extending in a southwest direction from central Wabash to central White counties, on the east side of the basin, the Hardinsburg is only 20–25 feet thick, whereas on the west, in White and Edwards counties, thicknesses range from 65 to 90 feet and on the east, along the eastern borders of Wabash and Lawrence counties, they are about 90 feet.

Golconda formation.—The Golconda formation may be divided into five distinct zones which are persistent throughout the basin. A generalized section follows.

Description	Thickness in Feet
Shale, red, green, and dark gray, partly calcareous; interbedded with dolomite, argillaceous, lithographic, red, brown, and green, grading to limestone	0–40
Limestone, oölitic, speckled white to brownish and dark gray, coarse-grained, partly dolomitic, in places cherty; partings of dark gray shale increasing downward	30–55
Shale, calcareous, red, green, brown, gray; some limestone, argillaceous, very fine-grained to coarsely crinoidal, gray, green, and red; zone becomes sandy eastward, grading to siltstone and sandstone in lower part, known as "gas sand" in Lawrence County	20–35
Limestone, more or less argillaceous and dolomitic, partly oölitic, speckled brownish gray, very fine- to coarse-grained; interbedded shale, dolomitic, dark brownish gray, contains pink bryozoa in the top layer; lithographic limestone at base in western part of area; zone becomes sandy eastward.	30–60
Shale, calcareous, green and red, containing some lenses argillaceous limestone, zone increasingly sandy eastward	5–40

The lithographic character of the vari-colored dolomite occurring in the upper shale zone is unique. The oölitic speckled limestones of the Golconda are similar to the limestone typical of the Glen Dean formation. The contact of the Golconda and the underlying Cypress is gradational. However, the base of the dominantly calcareous shale and limestone is usually considered the base of the Golconda.

The Golconda formation is 100–120 feet thick in the northwest, north, and northeast part and 140–180 feet thick along the southern part of its area of occurrence in Illinois. Like the Glen Dean, the Golconda is relatively thin along a belt extending through the middle of Fayette County southward along the general region of the Du Quoin anticline, along which belt several important oil fields are aligned. On the other hand the formation reaches its greatest thickness of 270 feet in the area directly east of this belt in eastern Jefferson County.

Cypress sandstone.—The Cypress sandstone is calcareous, light gray to white, very fine- to fine-grained and friable with a thin shaly to silty zone at the top in most of its section throughout the basin. However, the whole formation grades laterally into shaly sandstone, especially where the formation is thin. As previously noted, it is difficult to determine its contact with the overlying Golconda, partly due to the downward-increasing sandiness of the basal Golconda red and green shales, and also partly because of the tendency of these shales to cave and mask the true character of the samples. Ordinarily the top of the Cypress is marked by bright green quartzitic siltstone, though such a siltstone is found in some places above the base of the Golconda. Two thin coals, each only a few inches thick, are found in some places in the upper part of the Cypress in the Clay, Richland, and Wayne counties region. The Cypress is unconformable on the Paint Creek formation below.

The thickness of the Cypress sandstone ranges irregularly in the basin between 20 and 60 feet. However, thicknesses of 140 feet or more are attained in an area near the oil fields of Clay, Richland, and Wayne counties, whereas the thicknesses in the surrounding areas are less than 100 feet. Likewise in an area comprising eastern Perry and Jackson and western Franklin and Williamson counties, thicknesses of 100–140 feet are attained. In some localities, as in Fayette County, it is reported that no Cypress is encountered, but it is likely that at such places the sandstone is shaly and, possibly, grades to shale.

Paint Creek formation.—The Paint Creek formation consists of alternating vari-colored shales and limestones, with some sandstone beds. The contact of the overlying Cypress sandstone on the Paint Creek is sharp in most places. The shales are generally calcareous and brightly colored with various shades of red, green, brown, and gray. The limestones are also variable in color, being light to dark gray and brown with some pink to red. In texture they range from lithographic to coarsely crinoidal, and they are more or less argillaceous, sandy, oölitic, and fossiliferous. In the western part of the basin a prominent marker of the base of the formation is a brightly speckled, red, green, brown, and gray coarsely crinoidal limestone. Sandstone beds are more prominent in the eastern part of the basin, and in White and Gallatin counties the formation is divided into three members, consisting of upper and lower shale and limestones and a middle sandstone.

The Paint Creek formation is 100 feet or more thick along the western border of its area and eastward from Perry and Jackson to White and Gallatin counties. Northward it thins to an average of about 60 feet in Clay and Richland counties and to about 40 feet in Lawrence County. South of the broad area of 100-foot thickness the formation thins within a short distance to 20 feet and in places disappears entirely.

Bethel sandstone.—The Bethel sandstone, locally called the "Benoist sand," is white to gray and light green and very fine- to fine-grained, having partings here and there containing flakes of carbonaceous material and a little mica. Limestone and shale pebbles are commonly present near the base. Where the formation is thin it is shaly.

The thickness of the Bethel sandstone averages about 25 feet but ranges from 15 to 50 feet in most of its area of occurrence in the basin. In places it is less than 10 feet thick. In most of the southern counties of the area, however, the thickness increases irregularly southward so that it is more than 80 feet in certain areas.

Renault formation.—The Renault formation is composed of a wide variety of sediments. Where it is thickest in the deepest part of the basin it consists mostly of limestone with minor amounts of interbedded shale and a few thin beds of sandstone. Where it is thinner the formation becomes increasingly shaly and sandy. The limestones are generally more or less argillaceous and vary in texture from very fine- to coarse-grained. Oölitic rock is common, ordinarily being brownish gray and speckled, but in places forming beds of pure light gray limestone similar to the typical "McClosky" oölite of the Ste. Genevieve formation. Cherty and sandy limestones are present irregularly in the formation. Speckled pink, green, and light gray crinoidal limestone containing pink and bluish white chert replacements occurs in the lower part of the formation in some areas. The shales are generally calcareous and dark brown to dark gray, but red and green shales are common, being somewhat less brilliant in color than the Paint Creek shales. The sandstones are lenticular and more or less argillaceous. Breccias and conglomeratic zones are not uncommon in the Renault formation.

The Renault formation has its maximum thickness of about 100 feet in a north-south belt about two counties wide in the deepest part of the Illinois basin, extending from Pope County to Edwards County. Away from this area the formation ranges in thickness from 10 to 50 feet.

Aux Vases sandstone.[3]—The Aux Vases sandstone is calcareous, very fine- to fine-grained, and greenish gray to gray and pink. It contains numerous gray, pink, and yellow oölites, and hematite is commonly present. In diamond-drill cores it is observed to contain limestone pebbles in zones anywhere from top to bottom. In about the middle of the formation a sandy oölitic limestone is persistent through the central and eastern part of the basin. In places the sandstone grades to dark gray sandy shale and green argillaceous siltstone. Lenses of brown dolomite occur irregularly in the lower part of the formation.

The Aux Vases sandstone becomes thickest toward the southwest, being 125–150 feet thick in Randolph, Perry, and Jackson counties.

[3] It is not certain that all of these strata belong to the Aux Vases formation. Part of them may be the equivalent of the Hoffner member of the Ste. Genevieve formation which crops out in Union County. However, in view of the impossibility of differentiating the two formations in subsurface studies at this time, the general practice of designating all of them as Aux Vases is provisionally continued. The Hoffner beds are described by F. F. Krey, "Geology and Mineral Resources of the Dongola Quadrangle," *Illinois Geol. Survey unpublished manuscript*, and by J. Marvin Weller and A. H. Sutton, "Mississippian Border of the Interior Basin," *Bull. Amer. Assoc. Petrol. Geol., unpublished manuscript.*

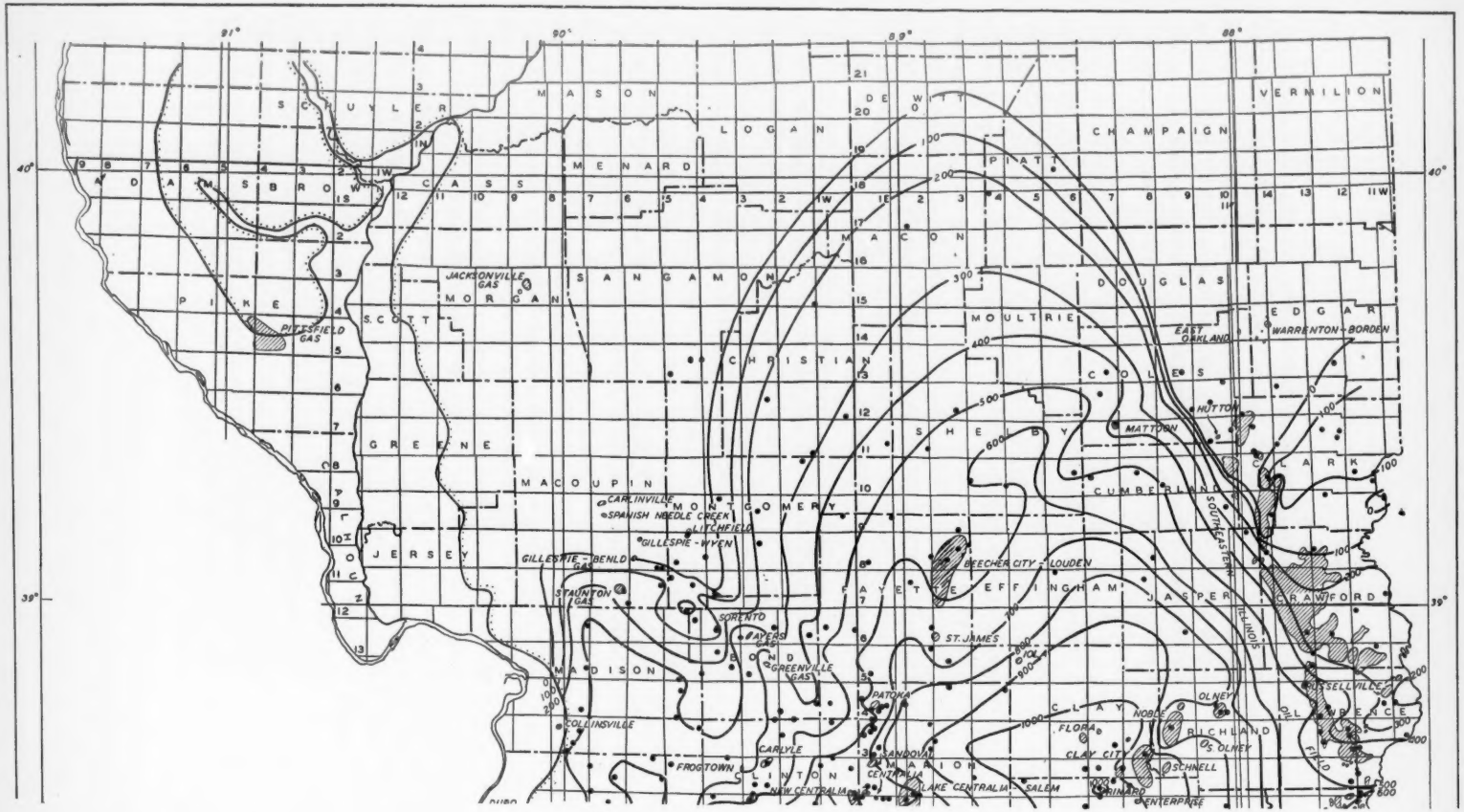
Northward along the western border of the Aux Vases area and in an area extending somewhat south of east through the north half of Bond and the southern part of Fayette to the northeastern part of Marion County, it is generally 100 feet or more thick. The formation thins eastward to about 10 feet along the eastern edge of the Aux Vases area, disappearing entirely in some localities.

ISOPACH MAP

Much of the oil produced in Illinois has come from the lower part of the Chester series below the top of the Cypress sandstone and from the upper part of the underlying Ste. Genevieve formation. Widespread uplift, deformation, and erosion previous to Pennsylvanian deposition established certain structural trends which seem to have been influential in the accumulation of oil in most of the Illinois fields. The isopach map (Fig. 3) shows the thickness of the Chester series from its top at the contact of the overlying Pennsylvanian system to the base of the Aux Vases sandstone.

Two major anticlinal belts were produced: (1) on the east the LaSalle anticline, which extends south-southeast along the eastern boundary of the Illinois basin, and (2) on the west, a southeastward anticlinal belt which extends along a line through Carlinville and Centralia, reaching into the middle of the Illinois basin, which is here designated as the Carlinville-Centralia anticlinal belt. The two anticlinal belts may be visualized as uplifts extending southeastward into that larger basin of Chester sediments which reaches from the Ozarks of Missouri to the Cincinnati arch of Indiana.

The LaSalle anticline is responsible for the formation of the major features of the old southeastern oil fields of Illinois. It is an asymmetrical fold having a gentle northeast dip and a sharp dip of 1,000–1,500 feet in a distance of a mile or two on the southwest. The uplift and subsequent erosion caused the Chester series to be entirely removed in a v-shaped area north of the northwest corner of Crawford County. From Douglas County southeast into Crawford County the sharply upturned edges of the Chester series were truncated along the steep edge of the anticline, as indicated by the closely spaced isopachs. Southeastward, however, the sharp west dip of the anticline, although present in the structure, is not revealed in the isopachs. In contrast, the isopachs spread apart as the result of erosion after broad domal uplift. This is interpreted as indicating that the development of the sharp westward dip was a progressively southward movement, and that the dome from Crawford to Wabash counties was covered and protected by Pennsylvanian sediments by the time the development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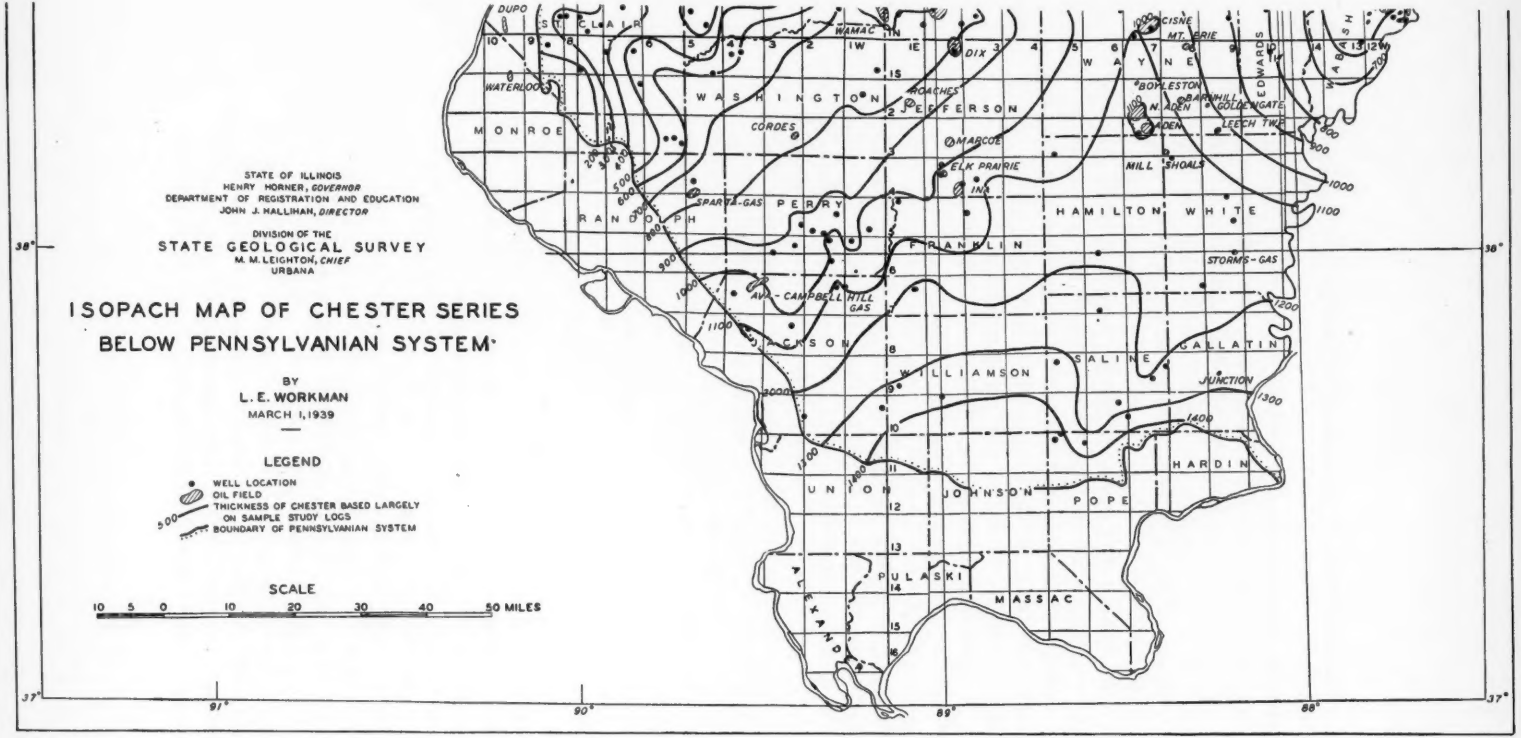

FIG. 3.—Isopach map of Chester series below Pennsylvanian system.

of the sharp westward dip had proceeded southward as far as northern Crawford County.

A pre-Pennsylvanian syncline extends northeast across the LaSalle anticline in central and northeast Clark County, and parallel with this in Crawford County is an anticline where Chester sediments are thin or have been entirely removed. It is possible that additional data may reveal this anticline to have a direction in line with the Clay City and Noble fields.

A minor anticlinal axis southwest through Lawrence County is also shown. Numerous evidences of southwest cross-folds and related phenomena along the LaSalle anticline should be significant in the study of structural trends on the anticline and in the basin.

Pre-Pennsylvanian movements were an important factor in the formation of structures in the Richland, Clay, and Wayne counties area, evidenced by thinning of the Chester series and erosion of the upper Chester formations.

The Carlinville-Centralia anticlinal belt has been of great importance to the accumulation of oil and gas in Macoupin, Bond, Clinton, and Marion counties. Most of the fields in the central and western parts of the Illinois basin, with the exception of the Louden-Beecher City field, lie in this belt. The uplift caused a v-shaped indentation of the western border of the Chester similar to that produced by the LaSalle anticline. The regional uplift seems to consist of two or three parallel lines of relatively thinner Chester series trending southeastward.

Of course, an isopach map of the Chester series does not give the whole structural history responsible for the accumulation of oil in this belt. Evidently cross-folds, produced either during the pre-Pennsylvanian period of diastrophism, or during or after Pennsylvanian time, formed local traps on the relatively broad folds. Thus the local structures forming the numerous oil and gas fields along the Carlinville-Centralia anticlinal belt do not show elongation along the direction of the belt but rather appear as domes or short anticlines, which are elongate in other directions.

The isopach map indicates that the Louden-Beecher City field was formed, at least in part, during the period of pre-Pennsylvanian diastrophism. This field has an arcuate form and seems to connect with the field south of Mattoon.

The map also suggests a northeast-southwest trending fold in southeastern Illinois extending through Saline County. Oil showings have been reported in the Tar Springs sandstone in wildcat wells of this general area, and a field is being opened up along the intersection

of this line with the Wabash River, taking oil from the McClosky limestone.

These features resulting from pre-Pennsylvanian diastrophism are also brought out in the pre-Pennsylvanian pattern of the formations of the Chester series in the areal geologic map (Fig. 1).

CROSS SECTIONS

Two geologic cross sections through the Chester series (Fig. 2), on the base of the Pennsylvanian as datum, are drawn along the lines *AB* and *CD* shown on the areal geologic map. The data used in these sections are almost exclusively from sample studies.

The north-south section, *AB*, is located as closely as possible to the middle of the Illinois basin, thus showing the thickest sediments. The greatest known thickness of Chester strata in Illinois is 1,450 feet at the location of well No. 19. The individual formations in general increase in thickness toward the basin. The thickness of that part of the Chester series below the base of the Palestine sandstone at a point between wells 23 and 24 is about 625 feet, whereas at well 19 the thickness of the same part of the Chester is 1,015 feet, showing a proportionate increase of 6:10.

The Mattoon structure is peculiar in that all Chester formations except the Cypress sandstone thin over the structure. This is not generally true of other structures in the line of the cross sections. It indicates that the area south of Mattoon had been a positive area of relative uplift through most of the time of the deposition of the Chester formations involved (Fig. 1). Inasmuch as this structure is considered to be aligned with the Louden-Beecher City structure, as indicated in the isopach map, it will be interesting to observe if these conditions continue into the latter field.

The west-east section, *CD*, shows the effect of the Carlinville-Centralia anticlinal belt on the west and the combined effect of the Clay City-Noble uplift and the LaSalle anticline on the east. The names of important producing fields are shown. Although the Centralia structure is the only local fold shown in this cross section, it is believed that, with sufficient data, other fields will show similar local uplifts.

The crest of the LaSalle anticline extends approximately through the location of well No. 16 in a line almost at right angles to the line of section *CD*. The section shows no effect of the sharp descent of 1,000 to 1,500 feet along the west limb of the anticline, but it does show the effect of the broad uplift. Here, also, there is some thinning of beds below the Cypress sandstone, but this may be natural thinning

toward the eastern borders of the Chester basin rather than the effect of any differential uplift along the anticline in early Chester time.

CONCLUSION

In conclusion it may be stated that the further study of the Chester series by isolating it in the foregoing manner from the effects of later Pennsylvanian structural movements should yield information of economic value to the oil industry. Likewise, significant trends are likely to be revealed by a study to locate more definitely the positive areas of relatively less depression during deposition.

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SUBSURFACE GEOLOGY OF IOWA (LOWER MISSISSIPPIAN) SERIES IN ILLINOIS[1]

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Urbana, Illinois

ABSTRACT

The Iowa, or lower Mississippian, series consists of the formations belonging to the Kinderhook, Osage, and Meramec groups. The Kinderhook group is made up almost entirely of shales with one or two thin limestones near the top. The Osage group is composed dominantly of silty shale and siltstone throughout the Illinois basin except in the extreme western and northwestern parts where the group can be separated into the typical Fern Glen, Burlington, Keokuk, and Warsaw formations. The Meramec group, consisting of the Salem, St. Louis, and Ste. Genevieve formations, is composed almost entirely of limestone and dolomite which lend themselves readily to separation by means of insoluble residues. The Iowa series reaches a maximum thickness of 2,000 feet in Gallatin County. This is probably due to thickening of the individual formations. Local variations in the thickness of the series and beveling of upper Iowa strata in Bond and Clark counties indicate some pre-Chester folding.

The strata beneath the Chester series and above the Devonian limestone in the southern Illinois basin have become of considerable importance to the oil geologist since the drilling of a producing well in the Devonian at Sandoval. The definite separation of the Ste. Genevieve, St. Louis, and Salem formations will probably depend to a large extent on the use of insoluble residues; nevertheless, there are strata that appear to be distinctive without the study of insoluble residues and they may be used for correlation purposes.

Ste. Genevieve formation.—The Ste. Genevieve formation (Fig. 1) consists, in descending order, of the Levias, Rosiclare, and Fredonia members. Its approximate boundaries in the Illinois basin are shown on the isopach map of the Iowa series (Fig. 3). Its total thickness is generally 165–175 feet, reaching a maximum of 200 feet in Jefferson, Franklin, and Pope counties. The formation generally thins toward the edges of the basin.

Levias member (6, p. 439).[3]—The Levias member consists partly of oölitic limestones and partly of fossiliferous shales. The insoluble residues are characterized by clay chips, white sugary chert, pink chert, and buff-colored finely botryoidal chert. The contact of the

[1] Read before the Association at Oklahoma City, March 24, 1939. Manuscript received, August 6, 1939. Published with the permission of M. M. Leighton, Chief, Illinois State Geological Survey.

[2] Subsurface Division, Illinois State Geological Survey.

[3] The name Levias has been adopted by the Illinois State Geological Survey to replace the older and more confusing name—"Lower O'Hara."
Numbers in parentheses refer to bibliography at end of article.

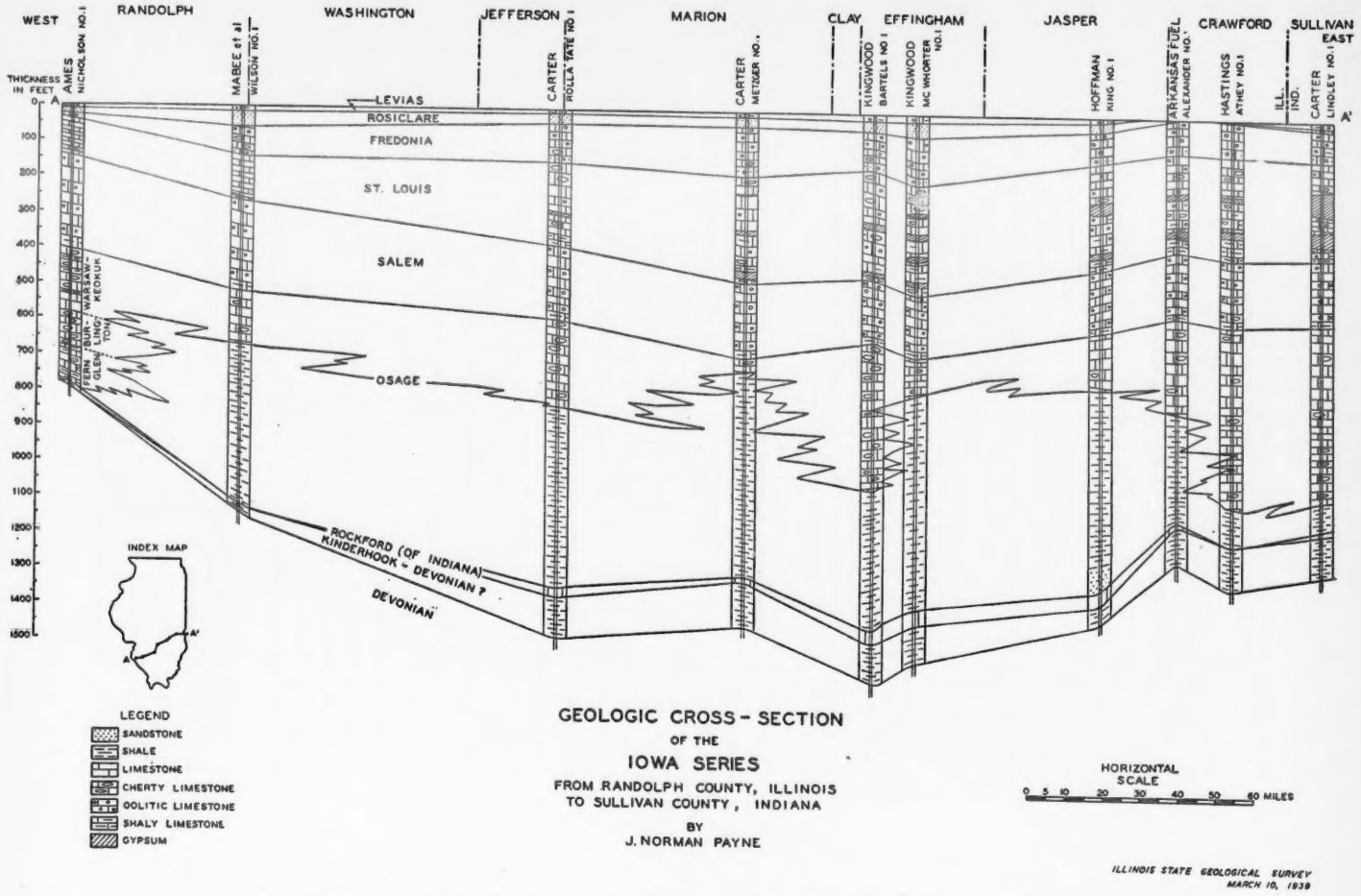


FIG. 1.—Geologic cross section of the Iowa series from Randolph County, Illinois, to Sullivan County, Indiana.

TABLE I

LITHOLOGIC DESCRIPTIONS AND THICKNESSES OF STRATIGRAPHIC UNITS OF IOWA (LOWER MISSISSIPPIAN) SERIES (EXCEPT KINDERHOOK GROUP) IN VARIOUS PARTS OF ILLINOIS BASIN

Stratigraphic Unit	*Southern Illinois Basin Franklin, Williamson, Southern Jefferson, Saline, Gallatin, Hamilton, and White Counties*		*Central Illinois Basin Fayette, Marion, Northern Jefferson, Clay, Richland, Wayne, Edwards, Effingham, and Jasper Counties*		*Southeastern Illinois Fields Clark, Crawford, and Lawrence Counties*	
	Thickness (Feet)	*Lithology*	*Thickness (Feet)*	*Lithology*	*Thickness (Feet)*	*Lithology*
Ste. Genevieve formation						
Levias member	25–70	Limestone, oölitic, light gray to brown, finely to coarsely granular containing some pink and yellow grains; some limestone, brownish gray, very fine-grained and dense; subordinate amounts of greenish black shale and brown dolomites. Some oil showings	20–30	Upper part shale, greenish black, platy, interbedded with limestone, brownish gray to brown, finely to coarsely granular, and dolomite, brown; lower part limestone, partly oölitic, brown to gray, fossiliferous, with some fine-grained beds and some shale layers; basal beds sandy	15–25	Limestone, light gray to light buff, very fine-grained to sublithographic, red and green spots; shale, green, gray, and red
Rosiclare member	20–80	Sandstone, calcareous, oölitic, light greenish gray, finely granular; limestone, sandy, oölitic, brownish gray, locally containing red oölites; shale, black, green, and red; erratic lenses of limestone breccia. Oil showings, some production	15–50	Sandstone, calcareous, oölitic, greenish gray, fine-grained, grading to siltstones, shales, and sandy, oölitic limestone; erratic lenses of limestone conglomerate, and breccia	10–40	Sandstone, calcareous, partly oölitic, green to gray, fine-grained; some limestone, sandy, oölitic, brownish gray; shale, sandy, green and gray
Fredonia member	105–175	Limestone, oölitic, light gray to light brown, finely to coarsely granular; some lithographic beds and dolomites; some lenses of chert, bluish gray, translucent. Producing zones	20–150	Same as in southern Illinois basin. Important producing zones	100–175	Limestone, oölitic, light gray and brown, with dense, sandy, and dolomitic beds; distinct dolomite horizons at or near top and near middle. Important producing zones

TABLE I—*Continued*

Stratigraphic Unit	*Southern Illinois Basin Franklin, Williamson, Southern Jefferson, Saline, Gallatin, Hamilton, and White Counties*		*Central Illinois Basin Fayette, Marion, Northern Jefferson, Clay, Richland, Wayne, Edwards, Effingham, and Jasper Counties*		*Southeastern Illinois Fields Clark, Crawford, and Lawrence Counties*	
	Thickness (Feet)	*Lithology*	*Thickness (Feet)*	*Lithology*	*Thickness (Feet)*	*Lithology*
St. Louis limestone	150–300	Upper half limestone, dolomitic, partly cherty, oölitic, brownish gray, finely granular; lower half limestone, dolomitic, partly argillaceous, cherty, dark brown to gray, finely granular, with abundant dolomite and some gypsum beds. One producing zone	250–500	Same as in southern Illinois basin with two distinct gypsum horizons in lower part. Producing zones	250–350	Same as in central Illinois basin. Producing zones
Salem limestone	200–300	Limestone, dolomitic, slightly cherty, brown and gray, mottled, coarse-grained, with abundant *Endothyra* and *Ostracoda;* a few beds of finer-grained limestones, dolomites, and shales. Oil and gas showings reported	175–220	Same as in southern Illinois basin, but practically entire formation made up of oölitic limestone with abundant *Endothyra.* Oil showing reported in Edwards County	140–200	Same as in central Illinois basin. Producing zones
Osage group	750–1,000	Varying thicknesses of limestone, light gray to light buff, coarse-grained, very fossiliferous; grading down to limestone, silty, brown, interbedded with shales, siltstones, and sandstones	600–1,000	Same as in southern Illinois basin	600–900	Same as in southern Illinois basin. Production from "Carper sand" in Clark County

Levias member with the overlying Aux Vases formation of the Chester series is not sharp and at some places appears gradational. The Levias member grades imperceptibly into the subjacent Rosiclare member.

The Levias member varies somewhat in thickness but is present in the greater part of the Illinois basin. Its average thickness is about 20 feet but 50 feet was penetrated in the Ohio Oil Company's Perry Hancock well No. 1, Sec. 4, T. 13 S., R. 5 E., in northwestern Pope County.

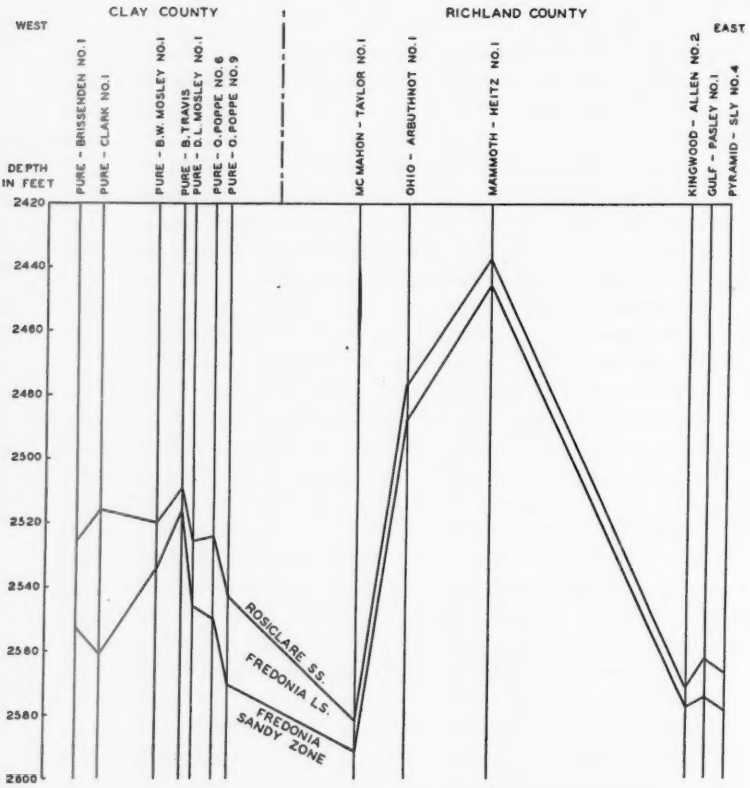
Rosiclare member.—The Rosiclare member varies lithologically but is dominantly sandstone containing lenses of shale, sandy limestone, and limestone breccia. Small rounded chert grains are plentiful in the insoluble residues from the basal part of the member. Sand showing more or less regeneration is the dominant residue.

The thickness of the Rosiclare member varies considerably within short distances but is generally 25–30 feet. As much as 75 feet has been penetrated in wells in Jefferson and Franklin counties.

No evidence of unconformity has been recognized beneath the Rosiclare sandstone where it crops out in southern Illinois and western Kentucky but an unconformity may occur at this position northward in the basin. This is suggested by: (1) considerable variation in the interval between the base of the Rosiclare and the top of a distinctive sandy zone in the Fredonia in the Clay City-Noble area (Fig. 2), (2) rapid increase and decrease in the thickness of the Rosiclare member, (3) a very sharp decrease in the amount of residues from basal Rosiclare beds as compared with upper Fredonia beds, (4) an apparent overlap of lower Fredonia beds by the Rosiclare along the margins of the basin, and (5) areas of channel-like thinning of the Fredonia in southwestern Illinois.

Fredonia member.—The Fredonia member is composed mostly of oölitic limestones but contains numerous beds of fine-grained limestones, dolomitic limestones, and dolomites and some shale beds.

The McClosky oil-producing zone in the Fredonia member is porous, oölitic limestone with more or less crystalline calcite in the interstices. The porosity of, and to some extent the production from, the McClosky "sand" depends on the amount of interstitial calcite. This type of rock is found at several horizons through the Ste. Genevieve formation and may be oil-stained whether it occurs at the top or bottom. In the Clay City, Noble, and Olney areas the highly productive zones are generally within 25 or 30 feet of the top of the Fredonia member but some production has been obtained as deep as 100 feet in the limestone. In southern Jefferson County production has been obtained as much as 50 feet below the top of the Fredonia.



CROSS-SECTION SHOWING VARIATION IN INTERVAL BETWEEN BASE OF ROSICLARE SANDSTONE AND TOP OF FREDONIA SANDY ZONE ("SUB-ROSICLARE") IN CLAY CITY, NOBLE & OLNEY FIELDS

ILLINOIS STATE GEOLOGICAL SURVEY
MARCH 10, 1939

FIG. 2.—Cross section showing variation in interval between base of Rosiclare sandstone and top of Fredonia sandy zone ("Sub-Rosiclare") in Clay City, Noble, and Olney fields.

In the Lake Centralia-Salem area the large production from the Ste. Genevieve formation will probably come from the upper 30 feet of the Fredonia member, which is for the most part typical McClosky that has undergone varying degrees of dolomitization. From these data it appears that a thorough test of the Ste. Genevieve formation can not be said to have been made until the well has been drilled completely through it.

Certain dolomites or highly dolomitic horizons in the Fredonia member seem to be reliable correlation beds. The first of these, a dolomite at or near the top, is restricted to the southeastern fields; the second, extending over most of the basin, occurs 40–50 feet below the first zone and about 70 feet above the base of the formation.

The insoluble residues from the Fredonia member are made up of a relatively small proportion of chert, which is rounded to botryoidal, dense to sugary or chalky, vitreous, and translucent, and in general a relatively high proportion of very fine to coarse regenerated sand. Fragments of siliceous foraminifera are rather common. In the lower 15–20 feet of the formation there is a general increase in the proportional amount and coarseness of sand and of rounded pebble-like grains of white to dark gray chert. The Fredonia is ordinarily 130–140 feet thick in the central part of the basin and thins west and northwest.

St. Louis formation.—The St. Louis formation is composed chiefly of fine-grained dolomitic and cherty limestones, with some oölitic, argillaceous, and sandy beds. Two widespread gypsum horizons occur in the lower part of the formation, the tops being respectively about 175 feet and about 50 feet above the base. The basal part of the St. Louis formation is commonly marked by argillaceous and silty limestone and dolomite.

Some beds in the St. Louis formation merit attention in prospecting for oil. The upper part of the limestone, where overlain by Pennsylvanian or Chester formations, may be porous enough as a result of weathering to be oil-producing (4, pp. 145–50). In the southeastern fields the formation, notably the upper part, contains porous petroliferous dolomites. In several wells in Jefferson and Franklin counties a porous limestone zone is present about 100 feet below the top of the formation. One well is producing from this zone.

The residues from the upper 30–40 feet of the St. Louis formation differ from those of the Ste. Genevieve in consisting of much white to buff, chalky to dense, angular, doloclastic chert. Silt, fine sand, clay chips, and white siliceous foraminifera are also common.

The maximum thickness of St. Louis formation thus far penetrated

in drilling is in northern Edwards County where it is 500 feet thick. In general the formation thins westward (Fig. 1).

Salem formation.—The Salem formation is an oölitic, very fossiliferous, mottled limestone having a characteristic chalky appearance. In several areas the rock has been found to have porous zones. The base of the formation is commonly marked by silty, argillaceous dolomite. The limestone ordinarily has a small percentage of insoluble residues typically consisting of (1) brown, glistening, sugary, crystalline silica or chert, (2) white, porous, chalky, dull chert, (3) porous, brown clay flakes, and (4) varying small amounts of very fine to medium sand.

In the Westfield pool of Clark County some oil production is believed to come from the Salem (4, pp. 125, 145). Gas with a little oil has been produced from the limestone in the Jacksonville gas field in Morgan County (1, pp. 3, 7). Showings of oil have been reported from the Salem in wells elsewhere in the basin.

In the north part of southern Illinois the average thickness of the Salem is approximately 130 feet, but southward the formation thickens. The cross section (Fig. 1) shows a thickening from Sullivan County, Indiana, southwestward to Randolph County, Illinois. The maximum thickness thus far penetrated in drilling is 300 feet in Howard Forester's Forester No. 1 well, SW. $\frac{1}{4}$, NW. $\frac{1}{4}$ of Sec. 5, T. 6 S., R. 1 W., Perry County.

OSAGE GROUP

In most of the Illinois basin the Osage group is similar to the Borden group of Indiana (5), consisting of silty shales, siltstones, and sandstones with lenses of limestone, but along the western and northwestern borders of the basin the rocks are like the standard Mississippi Valley section of Fern Glen, Burlington, Keokuk, and Warsaw formations, which are dominantly cherty limestones. Some of the limestones of the siltstone facies are reef-like in character, being composed mostly of bryozoan and crinoid remains.

A widespread occurrence of oil-producing zones in the Osage is very doubtful. Although some of the reef-like bryozoan limestone has good porosity, the rock is so erratic that its occurrence on structure is highly speculative. However, the sandstone which occurs near the base of the Osage in certain areas may be productive if it occurs on structure.

In Clark County there is a producing sandstone known as the "Carper sand," which has been reported as being in the Kinderhook (3, p. 2, and 4, pp. 39, 150), but careful review of all logs in the vicinity

of the Carper farm, Sec. 30, T. 10 N., R. 13 W., and a comparison with sample study logs also in the area reveals the fact that the "Carper sand" is basal Osage. The sandstone is similar to, and grades imperceptibly into, the Osage above. The "Carper sand" is extensive in the southeastern part of the basin but is variable in thickness.

KINDERHOOK GROUP

Below the base of the "Carper sand" there is 5–20 feet of green, structureless shale which belongs to the Kinderhook group. Beneath the shale is a lithographic limestone similar in lithology and stratigraphic position to the Rockford formation of Indiana (2, pp. 486, 487). This limestone is a good correlation bed throughout most of southern Illinois. It is about 30 feet thick in the central part of the basin and thins east and west (Fig. 1). The Rockford limestone is underlain by black to dark brown *Sporangites*-bearing shale which averages about 100 feet in thickness. A calcareous sandstone containing phosphatic nodules occurs locally at the base of the shale and above the Devonian limestones.

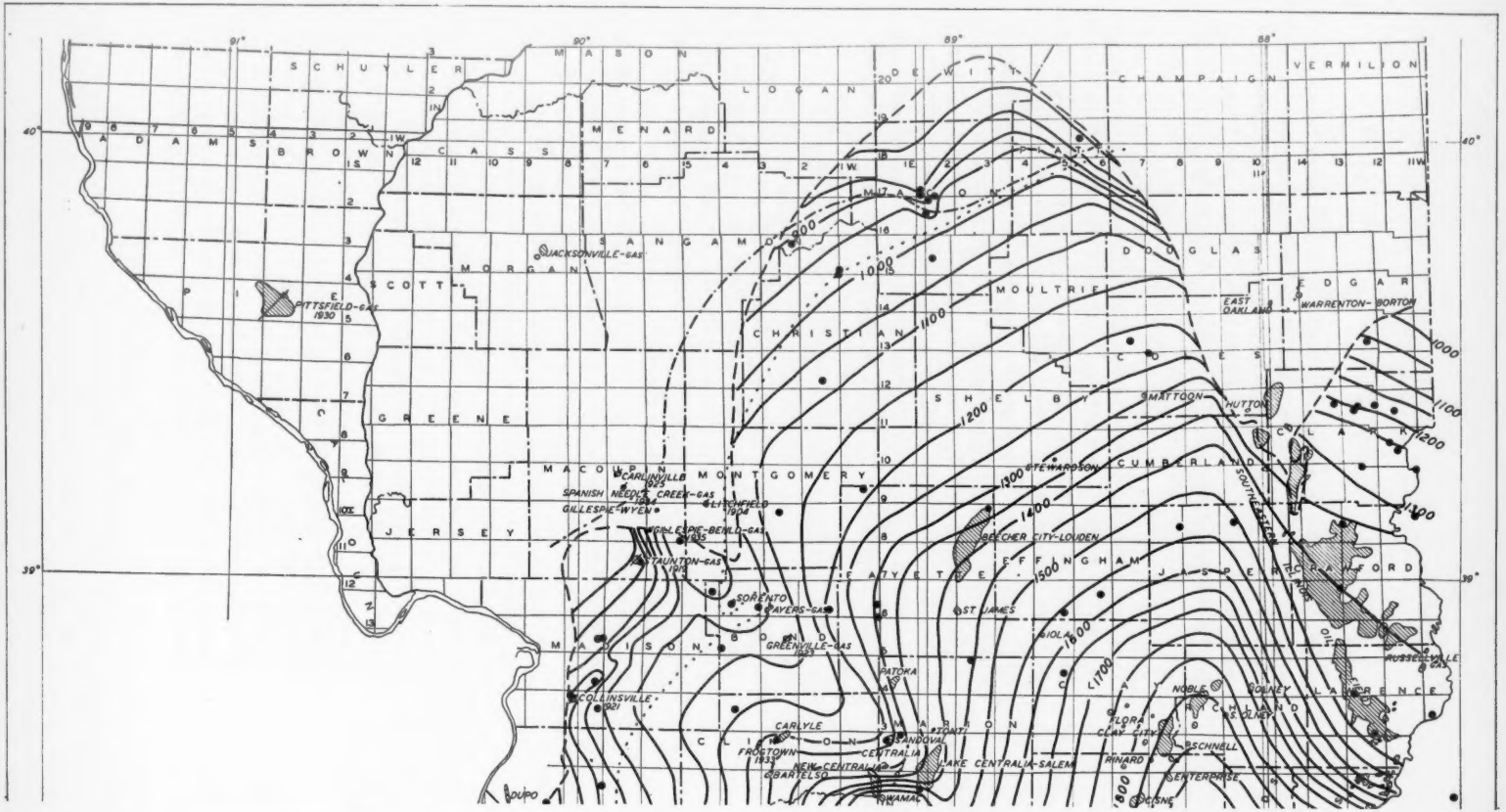
THICKNESS OF IOWA SERIES

In the aggregate the Iowa series thickens eastward and southward to a maximum of about 2,000 feet in Gallatin County (Fig. 3). Two prominent structures are revealed by thinning of the series on the structures—the LaSalle anticline in the east and the Carlinville-Centralia anticlinal belt in the west.

The thinning and complete removal of the Iowa series on the more northern parts of the LaSalle anticline is probably due to erosion prior to the deposition of the Pennsylvanian strata. Farther south in the area covered by Chester formations, the structure shows no effect on the thickness of the Iowa series.

The Carlinville-Centralia anticlinal belt extending through southeastern Macoupin and central Bond counties may be due to a structure of pre-Chester age. The greatest decrease in thickness of the Iowa series over this area amounts to about 175 feet, of which a maximum of only 70 feet can be attributed to thinning of the Ste. Genevieve formation. Likewise there is thinning of other Iowa formations. It is believed, therefore, that this belt was a positive area in pre-Chester time.

Minor structures that seem to have been formed prior to Chester deposition are found at Collinsville, Decatur, and in eastern Clark County. These areas of relatively thin Iowa series seem to be due to removal of upper Iowa beds of either Ste. Genevieve or St. Louis age.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EDGAR
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JACKSONVILLE-GAS
PITTSFIELD-GAS 1930
CARLINVILLE 1924
SPANISH NEEDLE CREEK-GAS 1924
LITCHFIELD 1924
GILLESPIE-WYEN
GILLESPIE-BENLD-GAS 1925
STAUNTON-GAS 1925
SORENTO
PAYERS-GAS
GREENVILLE-GAS 1923
COLLINSVILLE 1921
CARLYLE
FROGTOWN 1933
NEW CENTRALIA
BARTELSO
CENTRALIA
SANDOVAL
LAKE CENTRALIA-SALEM
HOWARD
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ST. JAMES
VIOLA
FLORA
CLAY CITY
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DENNE
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EAST OAKLAND
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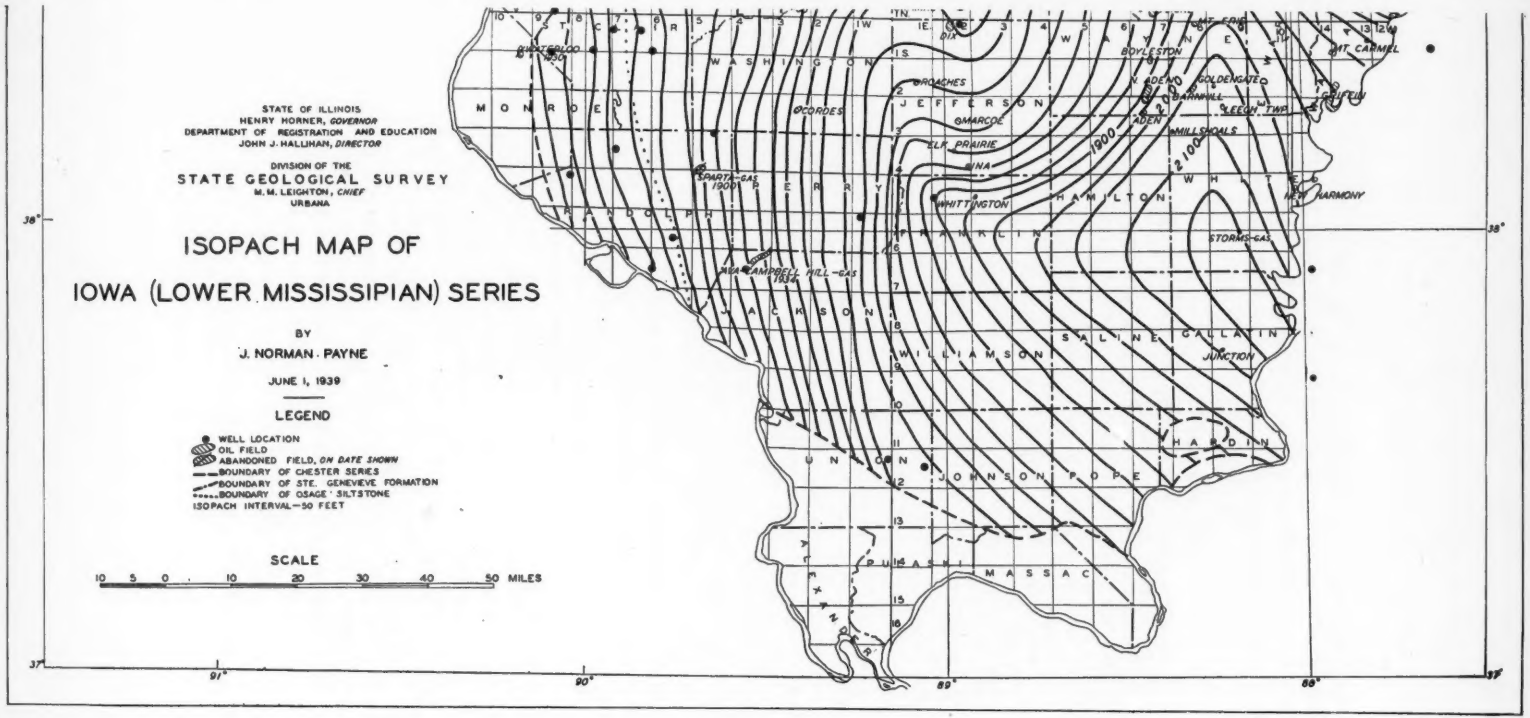

FIG. 3.—Isopach map of Iowa (lower Mississippian) series.

It is to be expected that other folds were formed in the basin prior to Chester time and it may be that pronounced structures, such as the Clay City, Noble, Louden-Beecher City, and Salem-Lake Centralia upfolds, may be reflected in the thinning of the lower Mississippian strata.

REFERENCES

1. BELL, A. H., "Recent Development in the Vicinity of Jacksonville," *Illinois Geol. Survey, Illinois Petroleum No. 11* (September 3, 1927).
2. CUMINGS, E. R., "Nomenclature and Description of the Geological Formations of Indiana," *Indiana Dept. Conservation Pub. 21* (1922), *Handbook of Indiana Geology*, Part IV, pp. 403–570.
3. MOULTON, GAIL F., "Areas for Further Prospecting Near the Martinsville Pool, Clark County," *Illinois Geol. Survey, Illinois Petroleum No. 4* (August 28, 1936).
4. MYLIUS, L. A., "Oil and Gas in East Central Illinois," *Illinois Geol. Survey Bull. 54* (1927).
5. STOCKDALE, PARIS B., "The Borden (Knobstone) Rocks of Southern Indiana," *Indiana Dept. Conservation Pub. 98* (1931).
6. SUTTON, A. H., and WELLER, J. M., "Lower Chester Correlation in Western Kentucky and Illinois," *Jour. Geol.*, Vol. 40 (1932), pp. 430–42.

DISCUSSION

LYNN K. LEE, The Pure Oil Company, Olney, Illinois (discussion received, August 28, 1939).—Mr. Payne is to be commended on his paper dealing with the Iowa series in Illinois. His work on insoluble residues, in addition to conventional lithologic studies, may well serve as a basis for the subsurface correlations of this section. Such correlations have heretofore been hazy due to the lack of concrete published material on the subject. His interpretation of the Osage group as being a contrasting lithologic phase of the Fern Glen, Burlington, Keokuk, and Warsaw formations of the Mississippi Valley is a logical one.

The placing of an unconformity at the base of the Rosiclare is a controversial point, which Mr. Payne recognizes as such. The writer is of the opinion that no unconformity exists at this contact, and that the evidence as given for this can more satisfactorily be explained by lateral variations of the lithologic units. Such variations are conspicuous in all three divisions of the Ste. Genevieve. The shales of the "Lower O'Hara" (Levias) vary considerably in thickness, yet the total thickness of this member remains fairly constant. The Rosiclare member in the Cisne, Clay City, and Noble areas varies in texture from very fine, sandy, limestone to medium-grained, calcareous cemented sandstone, containing large, rounded, frosted quartz grains. The beds of oölitic limestone, dolomites, and sandy zones of the Fredonia vary in thickness just as much in the middle of the formation as near the top. Since there is no suggestion of an unconformity within the Fredonia, I see no reason why the same stratigraphic condition at the top of the formation should be construed as indicating that one exists at that point.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 24, NO. 2 (FEBRUARY, 1940), PP. 237-281, 9 FIGS.

THE TYPE PERMIAN: ITS CLASSIFICATION AND CORRELATION[1]

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ABSTRACT

A review of the stratigraphy of the vast basin west of the Urals shows the relation of the five series into which the type Permian is divisible. These are correlated with the Permian deposits of South China and southwestern United States.

The limestones of the Russian platform, commonly considered Upper Carboniferous, are shown to be equivalent to the Artinsk detritals, which are generally recognized as Permian. The lower boundary of the Artinsk is shown to be not a constant stratigraphic horizon but the contact between overlapping facies.

Although no widely recognizable break has been demonstrated in the deposits of this basin from the beginning of the Upper Carboniferous into Permian time, a broad view shows that the rapid subsidence of the geosyncline over a very great area began with the incursion of the *Pseudoschwagerina* fauna. This beginning of a rapid evolution in the Uralian geosyncline is correlated with the regional hiatus at the base of the Wolfcamp series in America and a profound and regional break at the same horizon in the Orient. It is concluded, therefore, that the most natural lower limit of the Permian system is at the base of the *Pseudoschwagerina* zone, that is, at the base of the Sakmarian in the U.S.S.R., of the Wolfcamp in America, of the Chuanshan in South China, and of the Schwagerinakalk in the Carnic Alps.

INTRODUCTION

The original Permian rocks occupy a vast structural basin lying west of the Urals and measuring about 700 miles from west to east and 1,000 miles from north to south. This region is divisible into two major structural elements: (1) the Russian platform and (2) the Uralian geosyncline. Over the broad platform (the foreland) the Carboniferous and Permian formations lie nearly flat and are of moderate thickness; but as they pass eastward into the western flank of the Urals, the Permian formations thicken enormously and undergo a rapid change of facies.

When Murchison proposed the Permian system, he had spent only two summers in reconnaissance traverses of this vast area. He had done no detailed mapping, and the faunas were almost wholly undescribed. Indeed, it must be confessed that the reasons he then assigned for founding a new system would have little validity to-day if they had not been fortified by a vast array of data discovered since 1845.

At the same time, one can not read Murchison's great classic, *The Geology of Russia in Europe and the Ural Mountains*, without a feeling of amazement that in so brief a time he had grasped so ac-

[1] Read before the Association at Oklahoma City, Oklahoma, March 22, 1939. Manuscript received, November 29, 1939.

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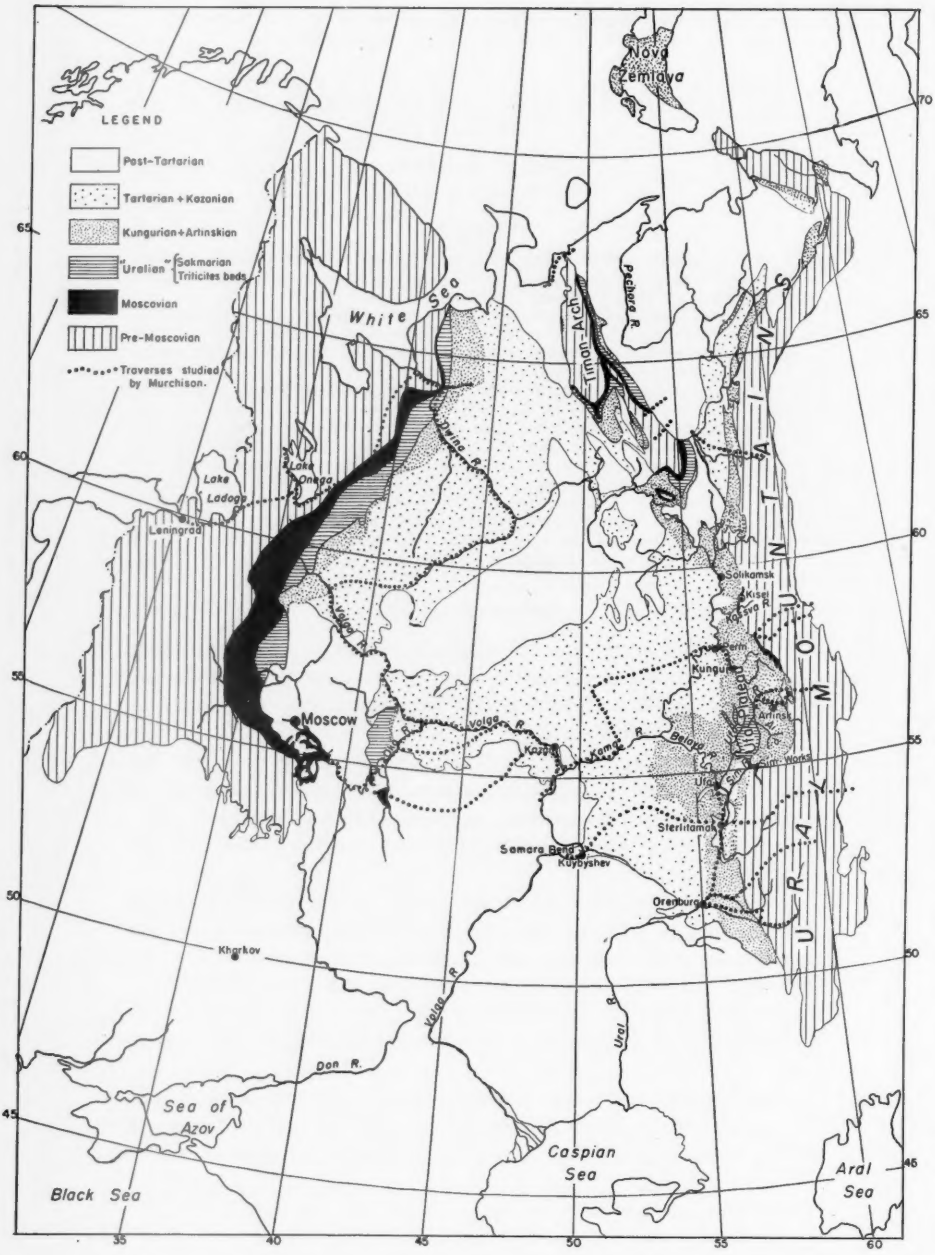


FIG. 1.—Map of type region of Permian system. Data from new geologic map of U.S.S.R. prepared for 17th International Geological Congress. Course of Murchison's traverse is that indicated in his map of 1845.

curately the major features of so extensive a region. The explanation lies in the fact that much work, mostly local, had already been done in Russia, and all this was made available to the British geologist.

Murchison's primary purpose in going to Russia was to see if the early Paleozoic systems recently established by him and Sedgwick for western Europe would be applicable farther afield. He went accompanied by the French paleontologist, Count de Verneuil, and was later joined by Count von Keyserling, a Russian geologist of prominence. By previous negotiation he went at the invitation of Czar Nicholas I, and all facilities for travel and guidance were arranged by Count de Cancrine, the Imperial Minister of Finance. Arriving in Moscow in the early summer of 1840, Murchison and his colleagues were cordially received and placed in the hands of Lieutenant Koksharof, a trained geologist from the Imperial School of Mines. This summer was devoted largely to the Ordovician, Silurian, and Devonian rocks along the northwest border of the country, but it included a trip up the Dwina River and across the western part of the great Permian basin. The next season (1841) began with exploration eastward from Moscow to Kazan and then up the Kama River to Perm, followed by seven traverses across the Ural Mountains. The last of these traverses found Murchison and his colleagues in the Orenburg region in the southeastern part of the Permian basin, whence they traveled overland to the Samara Bend of the Volga before turning south to visit the coal fields of the Don Basin.

Before leaving Moscow late in the fall, Murchison drew up a report to be laid before the Czar, presenting his interpretation of the geology of Russia, accompanied by a geologic map and a cross section from St. Petersburg to the Sea of Azov. In addition he addressed to Fischer de Waldheim, president of the Academy of Sciences at Moscow, a letter proposing the Permian system. Returning home, he discussed these results before the Geological Society of London, and during the winter published his letter to Fischer de Waldheim in the *Philosophical Magazine*.[3] This brief statement constitutes the original definition of the Permian system.

Murchison then set to work on the preparation of his great monograph, which appeared in two quarto volumes in 1845,[4] and in which the Permian system was for the first time described at some length.

Both during his sojourn in Russia and during the preparation of this monograph, Murchison enjoyed the use of all the information

[3] R. I. Murchison, "First Sketch of Some of the Principal Results of a Second Geological Survey of Russia," *Philos. Mag.*, Ser. 3, Vol. 19 (1841), pp. 417–22.

[4] R. I. Murchison, Eduard de Verneuil, and Count Alexander von Keyserling, *The Geology of Russia in Europe and the Ural Mountains*. London (1845).

previously obtained by Russian geologists. But he brought to his task a talisman not possessed by any of these, and one that made the local contributions of all former students of the region fit together like parts of a puzzle—he had a standard Paleozoic section freshly worked out in the British Isles and divided into *systems* that could be recognized, wherever found, on the basis of fossils. This enabled him to synthesize all that had previously been done and, even with such limited time for field investigation, to prepare a geologic map of fully one half of Europe in which the larger features are correctly portrayed.

Original definition of Permian system.—Although the general contour of the Permian basin was clearly shown by Murchison, his discussion of the stratigraphy was necessarily generalized and tentative. In the original definition of 1841, he discussed the Permian in the following sentences.

> Our last year's survey had pretty nearly determined the limits of the great tract of Carboniferous limestone of the North of Russia. On this occasion we have added to its upper part that remarkable mass of rock which forms the peninsula of the Volga near Samara, and which, clearly exposed in lofty, vertical cliffs, and charged with myriads of the curious fossils *Fusulina*, constitute one of the striking features of Russian Geology. [These are the beds of the zone of *Triticites* and correspond with the upper Pennsylvanian rocks of American geologists.]
>
> The Carboniferous system is surmounted, to the east, by the sandstone and conglomerates, to which I propose to give the name of "Permian System," because, although this series represents as a whole, the lower New Red sandstone (Rohte todte liegende) and the magnesian limestone or zechstein, yet it cannot be classified exactly (whether by the succession of the strata or their contents) with either of the German or British subdivisions of this age. Moreover the British lithological term of new red sandstone, is as inapplicable to the great masses of marls, white and yellow limestones, and grey copper grits, as the name of old red sandstone was found to be in reference to the schistose black rocks of Devonshire.
>
> To this "Permian System" we refer the chief deposits of gypsum of Arzamas, of Kazan and of the rivers Piana, Kama, and Oufa, and of the environs of Orenbourg; we also place in it the saline sources of Solikamsk and Sergiefsk, and the rock salt of Sletsk and other localities in the gouvernment of Orenbourg, as well as all the copper mines and the large accumulations of plants and petrified wood of which you [Fischer de Waldheim] have given a list in the "Bulletin" of your Society (anno 1840). Of the fossils of this system, some undescribed species of Producti might seem to connect the Permian with the Carboniferous aera; and other shells, together with fishes and saurians, link it on more closely to the period of the Zechstein, whilst its peculiar plants appear to constitute a Flora of a type intermediate between the epochs of the new red sandstone or "trias" and the coal measures. Hence it is that I have ventured to consider this series a "system."

This is the complete original definition of the Permian. To anyone familiar with the region, it is clear that the system, as then conceived,

included the strata now embraced in the Kungurian, Kazanian, and Tartarian series.

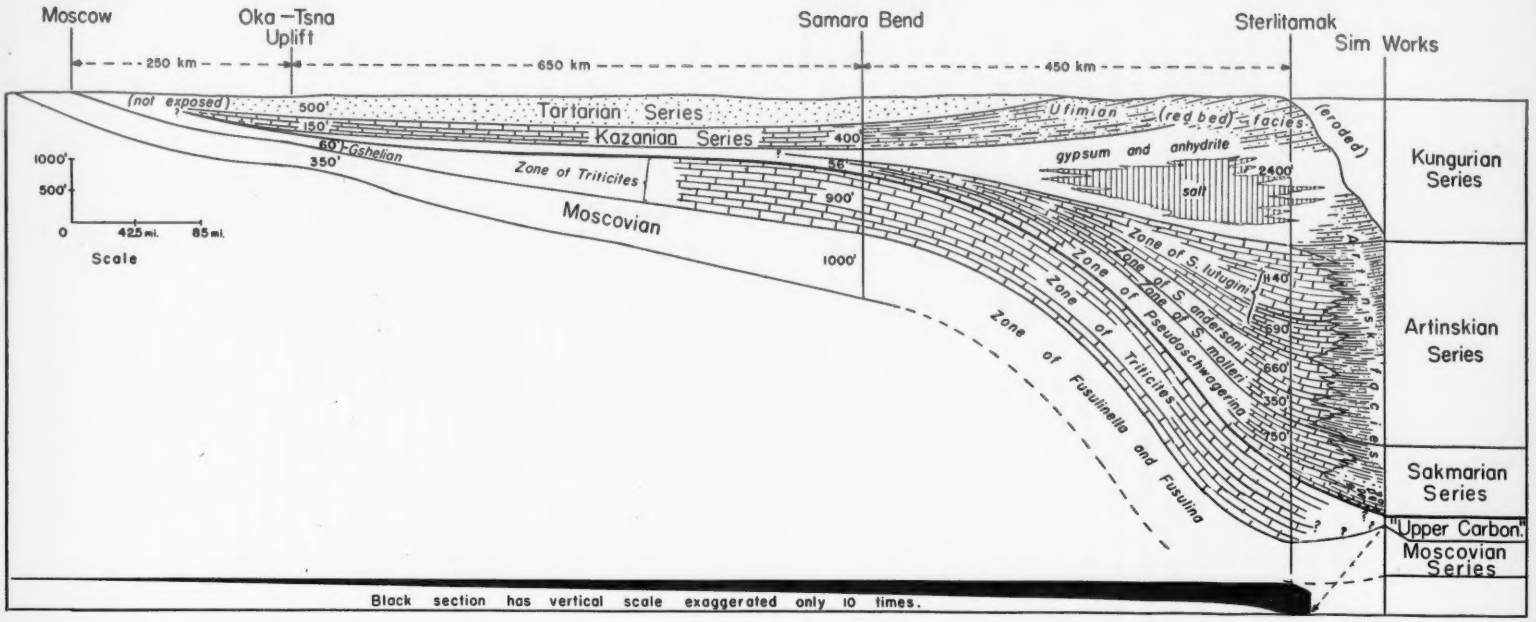
The information on which Murchison founded the system was secured chiefly in the valleys of the Kama and the Belaya, in the provinces of Perm and Orenburg, which include the geosyncline and the eastern part of the Russian platform. The name "was derived from the ancient kingdom of Permia within and around whose precincts the necessary evidence has been obtained."[5]

Members of the C-5 excursion of the Seventeenth International Geological Congress devoted nearly three weeks to the study of this type region of the Permian, under the capable guidance of Soviet geologists. This study included a traverse eastward from Moscow via the Samara Bend of the Volga to the Sterlitamak crossing of the south-central Urals, then northward along the strike for nearly 500 miles to Solikamsk and southwestward again by way of Perm and the Kama River to Kazan and Moscow. These two traverses across the Permian basin afforded an opportunity to see the chief divisions of the Carboniferous and Permian and to study their relations. The stratigraphy is complicated by the development of remarkable reefs in the limestones of the foreland, and by rapid changes of facies as the formations are followed eastward into the geosyncline. Thanks to the fine work of a number of Soviet geologists during the last two decades, much confusion has been cleared up and the basis has been laid for a correct understanding of the Permian stratigraphy. Nevertheless, differences of opinion persist even among the leading Soviet geologists, especially as regards the Carboniferous-Permian boundary.

ANALYSIS OF STRATIGRAPHY OF PERMIAN BASIN

The writer's understanding of the classification and general relations of the higher Carboniferous and Permian formations of the region is represented in Figure 2. It is a cross section, drawn roughly to scale, running from Moscow eastward across the Russian platform to the south-central part of the Uralian geosyncline. The data for it are drawn largely from the five localities indicated, where the succession has been studied and described. The vertical scale of the diagram is exaggerated about 100 times, requiring some distortion. Actually, the geosyncline is narrower and the eastward thickening is much more abrupt than is indicated; also, the distance between Sterlitamak and Sim Works is exaggerated. The solid black diagram at the base represents the section with the vertical scale exaggerated only 10 times.

[5] *Op. cit.* (1845), p. 138.



Section of the Permian and Upper and Middle Carboniferous Deposits of the Permian Basin, U.S.S.R.

FIG. 2.—Section across Permian basin from Moscow to Urals.

Since the base of the Permian is one of the chief problems presented, we must begin with undoubted Carboniferous beds and work upward. Furthermore, so much confusion surrounds the name *Uralian* that we have avoided its use and have tried, in so far as possible, to designate controversial beds as faunal zones the use of which would be free of ambiguity.

MIDDLE CARBONIFEROUS

Moscovian series.—The Moscovian series, now commonly called Middle Carboniferous by European geologists, corresponds closely with the Des Moines series of the Pennsylvanian rocks in the Mid-Continent region of the United States. It is well defined by its brachiopod fauna and especially by its fusulines. It was named by De Lapparent in 1902[6] and based on the succession in the Moscow basin. There it includes chiefly marly white limestones with *Spirifer mosquensis* and *Fusulina cylindrica* as the most characteristic fossils. In this region it has a thickness of nearly 600 feet and has been divided into four formations.[7] Its abundant fusuline fauna includes the genera *Fusulinella* and *Fusulina*, along with more primitive forms such as *Staffella*.

The Moscovian section is apparently similar in the Oka-Tsna uplift[8] but increases to a little more than 1,000 feet at the Samara Bend where it has been studied in recent bore-holes.[9] The increase in thickness eastward is due in part to the introduction of beds at both top and bottom of the section. Semichatova showed, for example, that at the Samara Bend, and farther east, the uppermost beds of the Middle Carboniferous constitute a zone characterized by *Wedekindellina*, which is not represented in the Moscow basin, but clearly belongs with the Moscovian series. The base of the section, on the other hand, includes at least 50 feet of limestone filled with minute globular fusulines such as *Staffella antiqua* but without any of the larger, fusiform genera. These beds, referred to the Namurian stage by Rauser-Chernoussova,[10] almost certainly represent the Bashkirian limestone which is discussed below. The lower 250 feet of the typical

[6] *Traité de Géologie*, 3rd Ed., Vol. 2 (1902), p. 819.

[7] M. R. Shvetzov *et al.*, "The Moscow Coal Basin," *Guidebook Seventeenth Inter. Geol. Congress* (1937), pp. 17–20.

[8] D. V. Nalivkin, "Moscow to Cuibyshev," *Guidebook Permian Excursion, Southern Part, Seventeenth Inter. Geol. Congress* (1937), p. 29.

[9] S. V. Semichatova, "Upper and Lower Boundary of the Middle Carboniferous Moscovian Stage," *Amer. Jour. Sci.*, Vol. 32 (1936), p. 224.
D. Rauser-Chernoussova, "The Upper Paleozoic Foraminifera of the Samara Bend and the Trans-Volga Region," *Studies Geol. Inst. Acad. Sci.* (Moscow), Vol. 7 (1938), pp. 69–167, Pls. 1–9.

[10] *Op. cit.*, pp. 80, 81, 150.

Moscovian is here marked by the introduction of terrigenous sediments, such as sands, clays, and glauconite, but the upper part remains essentially calcareous.[11]

Along the flanks of the Urals the Moscovian is more variable. In the bluffs of Sim River at Vavilova it is completely missing and the Upper Carboniferous rests on Middle Devonian.[12] At Sim Works it is represented by about 300 feet of unfossiliferous, dark greenish shaly beds which separate the Bashkirian formation from the Upper Carboniferous limestones.[13] But in the eastern part of the Orenburg region, near the south end of the Urals, the Middle Carboniferous is largely detrital, including sandstone and conglomerate, and attains the great thickness of 3,300–4,900 feet.

Bashkirian limestone.—Over a considerable region west of the central part of the Urals, there is a pure, compact limestone beneath the typical Moscovian, to which Semichatova gave the name Bashkiri limestone. It has a great abundance of minute fusulines such as *Staffella* and *Ozawainella*, but lacks the larger and fusiform genera that characterize the Moscovian. Semichatova regards these beds as Middle Carboniferous but older than the Moscovian.[14] The primitive character of their fusulines strongly suggests a correlation with the Bend limestone of Texas. Although Nalivkin correlated the Bashkirian limestone with the Namurian and tentatively referred it to the Lower Carboniferous,[15] the presence of abundant fusulines, as well as the brachiopod evidence cited by Semichatova, seem to the writer to strongly favor alliance with the Moscovian instead of the Visean, that is, to indicate a Middle Carboniferous age. This is also the decision recently reached by Khvorova.[16]

UPPER CARBONIFEROUS

General statement.—Between the Moscovian and the Sakmarian series in the eastern half of the Permian basin lies nearly 1,000 feet of limestones characterized by species of *Triticites* and by a rich brachiopod fauna; these beds correspond roughly with the Missouri and Virgil series of the Mid-Continent region in America, that is, with

[11] S. V. Semichatova, *op. cit.*, p. 224.

[12] M. M. Tolstikhina, "The Asha Works," *Guidebook Permian Excursion Seventeenth Inter. Geol. Congress, Southern Part* (1937), p. 116.

[13] D. V. Nalivkin, "The Sim Works," *Guidebook Permian Excursion Seventeenth Inter. Geol. Congress, Southern Part* (1937), p. 127.

[14] *Op. cit.*, p. 225.

[15] *Op. cit.*, p. 125.

[16] I. V. Khvorova, "Middle Carboniferous of the Western Slope of the Urals in Southern Bashkiria and the Orenburg District," *Bull. Soc. Nat.* (Moscow), Sec. Geol., Vol. 15 (1937), pp. 517–40.

the upper part of the Pennsylvanian system as it is recognized by American geologists.

Overlying this *Triticites zone* comes the Sakmarian series, which is the *Pseudoschwagerina zone* ["*Schwagerina* zone" of authors]. The Sakmarian is the undoubted equivalent of the Wolfcamp series in America, and is considered by many Soviet geologists to belong, with the *zone of Triticites*, in the Upper Carboniferous, and by other Soviet geologists and most American geologists is regarded as basal Permian. In the present discussion it is treated with the Permian.

Unfortunately, there is no generally accepted name for the *Triticites zone* alone. The name *Gshelian* was applied to that part of it which is represented in the Moscow basin, there only a few hundred feet thick (Fig. 2). Perhaps this name should be extended to the thicker sections farther east, though it is improbable that the type section of the Gshelian represents more than a small part of the *Triticites zone*, and further faunal work is required to demonstrate just what part is so represented. The name *Uralian* was introduced to include the *Triticites* beds and all the overlying "limestone of the Urals," which, as shown in Figure 2, represent not only the Sakmarian but the Artinsk as well. It has since been used in so many senses that it is shrouded in ambiguity as explained below. The need of a group name for the *Triticites zone* is evident but the writer defers to the Soviet geologists to select one, and for the sake of clarity will here refer to it only as a faunal zone.

Triticites zone.—These beds are perhaps best known at the Samara Bend of the Volga where Murchison saw them "clearly exposed in lofty, vertical cliffs, and charged with myriads of the curious fossils, *Fusulinæ*." Noinsky described the surface outcrops in detail in 1913[17] and the fusulines have been recently described by Rauser-Chernoussova in connection with the study of several deep well cores.[18] Here the *zone of Triticites* is about 900 feet thick[18] and is composed of light gray, buff-weathering limestones.

Passing under the redbeds east of Samara Bend, this horizon reappears along the western flank of the Urals as a rather pure, cliff-forming limestone. Deep wells in the Ishimbaevo oil fields south of Ufa reveal a thickness of about 1,200 feet. These beds do not come to the surface in the Ufa Plateau, but are exposed in the bluffs of Sim River at Vavilova which is about 100 kilometers east of Ufa. At

[17] M. Noinsky, "The Samara Bend," *Studies Soc. Nat.* (Kazan University), Vol. 45, Nos. 4–6 (1913), pp. 1–767.

[18] D. Rauser-Chernoussova, "The Upper Paleozoic Foraminifera of the Samara Bend and the Trans-Volga Region," *Studies Geol. Inst. Acad. Sci.* (Moscow), Vol. 7 (1938), pp. 69–167.

Vavilova they are well bedded, more or less dolomitized gray limestones bearing fusulines of the genus *Triticites* and having a thickness of approximately 1,000 feet.[19]

In this longitude these beds appear to hold their lithologic character and thickness far to the north for they are represented by zones $C\frac{1}{3}$ and $C\frac{2}{3}$ of Tolstikhina's section in the Kisel region approximately 300 miles north of Ufa. Members of the Permian excursion saw them along the Kossva River, where Tolstikhina[20] reported a thickness of about 1,300 feet (where they are cliff-forming limestones with corals, brachiopods, and foraminifera). In the Kisel region they rest on the Moscovian series, which is largely detrital, and are overlain by limestones of the Sakmarian horizon with *Pseudoschwagerina*.

East of Vavilova, however, the *Triticites* beds thin very abruptly, and at Sim Works are not more than 100 feet thick. The very interesting section at this locality is represented in Figure 3. Above the poorly exposed shaly beds of the Middle Carboniferous come well bedded, buff-weathering limestones in which some layers are filled with small species of *Triticites*. But within about 100 feet of the base occurs a bed of limestone breccia several feet thick, in the muddy matrix of which the *Pseudoschwagerina* fauna appears. The succeeding beds,

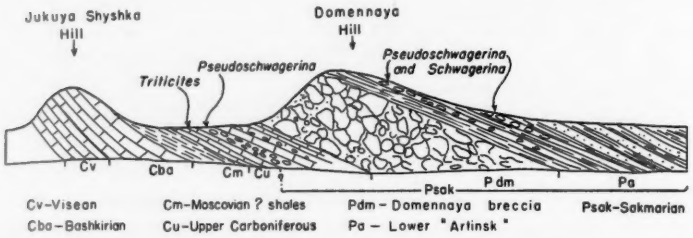


FIG. 3.—Section along bluffs of Sim River at "The Isthmus" at Sim Works, looking west.

about 200 feet thick, consist of limestones alternating with beds of limestone breccia. This horizon is succeeded by the Domennaya breccia, a single non-bedded mass 500–600 feet thick made of blocks of limestone ranging up to tens of feet in diameter, derived from the underlying formations, chiefly the Visean and the Bashkirian beds. This breccia is followed by a continuous section of approximately

[19] M. M. Tolstikhina, "The Asha Works," In *Guidebook Permian Excursion Seventeenth Inter. Geol. Congress, Southern Part* (1937), p. 116.

[20] M. Tolstikhina, "Materials for the Stratigraphy of the Upper Paleozoic in the Region of Kisel," *Notes All-Russian Min. Soc.*, Vol. 65, No. 1 (1936), pp. 1–40.

4,500 feet of Artinskian shales and siltstones. These have been divided into four zones, A, B, C and D. The lowest, zone A of the "Artinsk," includes several thin beds of fine-grained limestone conglomerate, the latter bearing, in the matrix, fusulines of the genera *Pseudoschwagerina* and *Schwagerina*. Ammonites are found near the middle of zone A.

The great Domennaya breccia appears to be a landslide breccia related to submarine faulting, and the several beds of finer breccia below are but precursors, indicating the beginning of disturbance near at hand as *Pseudoschwagerina* was making its first appearance. The complete and permanent change to detrital sediments following the great breccia emphasizes the importance of this movement.

Now, the *zone of Triticites* is represented by only about 100 feet of limestones below the first breccia with the earliest *Pseudoschwagerina*. The presence of that genus in the breccia and in the overlying zone A of the Artinsk indicates that this much of the section should be considered Sakmarian. Even if all the limestone between the Middle Carboniferous and the Domennaya breccia were considered part of the *zone of Triticites*, the total thickness would be only about 350 feet, or scarcely more than one third that of this zone at Vavilova.

The writer made a large collection from the *Triticites* bed at this locality, and a smaller one from the lowest *Pseudoschwagerina* horizon and has studied the fusulines in the hopes of determining what part of the *Triticites* zone is present here. The faunal zones established by Rauser-Chernoussova in the thick section at the Samara Bend provide a standard for comparison.

From the uppermost *Triticites zone* at Sim Works, 36 specimens were sectioned by the writer. The result is somewhat puzzling. There is a surprising variety of fusulines, including probably 6 species of *Triticites*, 1 of *Quasifusulina*, and 1 of *Schwagerina* [not *Schwagerina* of authors, which is *Pseudoschwagerina*]. Each of the latter genera is represented by a single section, and examination of hundreds of specimens from this collection, has produced no additional examples. The commonest species appears to agree best with *Triticites paraarcticus* Rauser-Chernoussova, which in the Samara Bend was limited to the lowest zone. But, on the other hand, the few specimens of more advanced type strongly indicate the upper part of the *Triticites zone*. If so, the *Triticites zone* is largely missing by unconformable overlap on the Middle Carboniferous. Possibly the calcareous part of the Moscovian is lacking here because of pre-Upper Carboniferous erosion.

The local field evidence did not indicate whether or not there is a

break at the base of the *Pseudoschwagerina zone*, but the fusuline fauna collected here by the writer includes *Pseudoschwagerina "princeps"* [of authors, not Ehrenberg], *Schwagerina uralica*, and *S. uralica* var. *sphaerica*, with none of the species from the underlying zone. This abrupt change suggests a considerable hiatus. Certainly the incursion of the *Pseudoschwagerina* fauna coincided with the initiation of an important tectonic disturbance in this area.

West of the Samara Bend the *zone of Triticites* thins greatly but whether by the loss of beds or by the thinning of individual members has not been determined. In the Oka-Tsna uplift the total thickness of these beds is only about 60 feet, and they thin to a feather edge near Moscow. They were studied by Nikitin who in 1890 proposed for them the term *Gshelian stage*. This name was first introduced in a preliminary announcement of his work on the geology of the Moscow basin.[21] He then stated that, having given attention to the composition and the correlation of the Carboniferous limestones of central Russia, he divides them into three stages (and not two as had been the custom). The middle one of these is the stage of *Spirifer mosquensis* [the Moscovian]. "The upper corresponds fully with the fusulina stage of Murchison, unknown up to now in central Russia but just discovered by the author."

In his monograph which appeared later in the same year,[22] Nikitin discussed the Gshelian more fully, stating that it consisted of dolomites and dolomitic limestones of yellowish or yellowish brown color. Furthermore he stated,

> All that now remains in the province of Moscow is hardly 20–30 meters thick. The unique locality where it is rich in fossils is about 50 km. east-southeast of Moscow between the villages of Retschitzy, Trochkowo and Glebovo, in the region of Gshel. . . . One other locality completes our knowledge of the Gshelian fauna. It is in the village of Roussavkina situated midway between Moscow and Gshel.

The fauna which he gave for the Gshelian included *Fusulina [Quasifusulina] longissima*, *Chonetes uralica*, *Spirifer supramosquensis*, and *S. saranae*.

Since Nikitin's work, the Gshelian beds have been found to be richly fossiliferous at other places in this general vicinity, notably in the great quarries near Voskresensky, where the present writer and his American colleagues, Miller, Newell, and Condra, had an oppor-

[21] M. Nikitin, "Note sur le calcaire Carbonifère du bassin de Moscou," *Bull. Com. Géol.*, Vol. 9 (1890), pp. 27–40.

[22] M. Nikitin, "Carboniferous Deposits in the Region of Moscow," *Mém. Com. Géol.*, Vol. 5, No. 5 (1890).

tunity to study them under the guidance of Professor M. S. Shvetzov, Mrs. S. V. Semichatova, and Miss I. Ivanova. In the Moscow basin these beds have been subdivided by Ivanov[23] into two horizons, as follows.

C_3^1 Omphalotrochus horizon. Limestone, magnesian limestone, and clay. Thickness, about 150 feet

C_3^2 Teguliferina horizon. Calcareous clays, marl, and limestone. Thickness, 130–150 feet

It may be noted that this thickness of 280–300 feet is somewhat greater than that given in the guidebook for the Permian excursion and about six times as great as that of the same horizon in the Oka-Tsna uplift.[24]

Collections from the Teguliferina horizon included small, slender *Triticites* along with *Quasifusulina longissima*, and abundant brachiopods including *Teguliferina*. The entire aspect of the fauna indicates an age approximately that of the beds exposed at Kansas City, that is, the lower part of the Missouri stage.

Since the name Gshel was applied to these deposits of slight thickness which almost certainly represent only the lower part of the *Triticites zone*, it is questionable whether it should be extended to include the entire zone at the Samara Bend and in the flank of the Urals.

PERMIAN SYSTEM

The "*Schwagerina* zone" of authors is still the subject of much controversy. Until recently Russian geologists generally classified it as Upper Carboniferous, but following the arguments of Beede in 1924, most American geologists have regarded this and equivalent beds as the base of the Permian. The latter interpretation is now preferred by some of the leading Soviet geologists as well as other European students of the Permian. While the writer believes these beds to be Permian, he will attempt here to present their actual stratigraphic relations as objectively as possible, reserving the arguments pro and con for a later section of this paper.

Ambiguity of term "Uralian."—Since the term Uralian has been so widely used in the discussion of these beds, it seems necessary here to review its history in order to clear away the ambiguity that surrounds it.

The name "Ouralian" [=English Uralian] was introduced by De Lapparent in 1902 in a general discussion of the subdivision of the

[23] A. P. Ivanov, "Dépôts du Carbonifère moyen et supérieur du gouvernment de Moscou," *Bull. Soc. Nat.* (Moscow), Sec. Géol., Vol. 34, Tome 4 (1926).

[24] D. V. Nalivkin, "Moscow to Cuibyshev," *Guidebook Permian Excursion Seventeenth Inter. Geol. Congress, Southern Part* (1937), pp. 28 and 30.

Carboniferous rocks of western Europe, and was intended for a marine series equivalent in age to the Stephanian coal measures. In the first use of the term[25] he stated that it is "applicable to the limestones of the Ourals with *Chonetes uralica* and large fusulines," and he added in a footnote, "It is the Gshelian of M. Nikitin." Further definition of the Uralian appears on page 865 of the same volume, where he discusses the Carboniferous system in Russia and states that

> in the Oural Basin a new marine stage, the Gshelian of M. Nikitin, our Ouralian, appears in the form of limestones with large fusulines, containing *Chonetes uralica, Conocardium uralicum, Productus cora, Marginifera* (*Productus*) *uralica, Spirifer saranae, Meekella eximia, Fusulina longissima* and *F. uralica.* It is in the upper part of this stage that cephalopods, such as *Prononites,* are developed along with foraminifera of the genus *Schwagerina* as well as *Fusulina verneuili.*[1] In the Moscow Basin, at Gshel, this horizon is represented by very fossiliferous dolomites. [De Lapparent's footnote ([1]) refers to Pavlow, *Ann. Geol. Univ.*, Vol. VII, p. 665.]

De Lapparent added that the Ouralian is succeeded discordantly by the Artinsk beds, which with their fauna and flora should be referred to the base of the Permian.

Finally, on page 871, he presented a correlation table in which the "Ouralien ou Stéphanian Étage" is represented by local formations in several regions. In the column devoted to the Ural region two divisions of the stage were indicated, the lower embracing the Gshelian beds, with *Fusulina longissima,* and the upper the limestones with *"Fusulina" verneuili, "Schwagerina,"* and cephalopods.

It is probable that De Lapparent had not seen the Russian section and had little knowledge of the beds concerned when he proposed the name Uralian. No one then suspected that more than half "the limestones of the Urals" was a facies of the Artinsk which he then placed in the Permian. As clearly shown in the diagram (Fig. 2), the original Gshelian beds are only about 60 feet thick and would correlate with mid-Pennsylvanian strata, whereas "the limestones of the Urals" crop out nearly 1,000 miles east of Gshel *and have a thickness exceeding 4,000 feet and a stratigraphic range that in the United States would extend from the base of the Missouri series in the Pennsylvanian to some horizon in the Leonard division of the Permian.*

The confusion portended by such vague definition was compounded by the appearance during the same year of Tschernyschew's great classic, "Die Oberkarbonischen Brachiopoden des Ural und des Timan."[26] His discussion of the stratigraphy began with the

[25] *Traité de Géologie,* 3rd Ed., Vol. 2 (1902), p. 819.

[26] *Mém. Com. Géol.*, Vol. 16 (1902), Tome 1, Text, pp. iii–viii, 1–749; Tome 2, Atlas Pls. I–LXIII.

east flank of the Timan arch, at the edge of the Arctic sea. There the "Upper Carboniferous" limestones crop out as a hogback extending southward along the eastern flank of the plateau, and Tschernyschew studied and illustrated four profile sections across this outcrop at intervals of 20–50 miles apart. These agreed well in the succession of beds and led him to establish a three-fold division as follows, in descending order.

C$_3^3$ *Schwagerina horizon*—±165 feet
C$_3^2$ *Cora horizon*—±330 feet
C$_3^1$ *Omphalotrochus horizon*—±200 feet

The lowest of these was observed to rest on the Middle Carboniferous [Moscovian] beds and the uppermost horizon was succeeded by detrital Permian beds or overlapped by Quaternary deposits. Tschernyschew listed characteristic species, chiefly brachiopods and corals, for each of these horizons.

After studying the Timan region, he journeyed southward approximately 500 miles to the Ufa Plateau and there studied sections along the Ai and Juresan rivers and attempted to apply the three-fold classification he had set up in the north, apparently basing his identification of the *Schwagerina horizon* and of the *Omphalotrochus horizon* on the brachiopod assemblages and not on the presence of the named zone fossils.

Thus he fell into two errors. In the first place, he failed to discover that in the Ufa Plateau the limestone section continues much higher stratigraphically than it does in the Timan Plateau (Fig. 4). In the second, as Tolstikhina later pointed out,[27] the brachiopod assemblage on which he relied to identify his *Schwagerina horizon* was a facies associated with bryozoan reefs and not limited to a definite horizon. Thus some of his best brachiopod collections supposed to be from the highest horizon in the Ufa Plateau (that from Mount Tastuba) were actually from the lowest. Later work has shown that "*Schwagerina*" [*Pseudoschwagerina*], does not occur in the upper part of the limestone succession in the Ufa Plateau but is limited to the lower part. Accordingly, Tschernyschew's succession for the Ufa Plateau was badly confused and in large measure inverted.[28]

Although he did not use the term Uralian (which was proposed after his work was in press), Tschernyschew's section immediately became the accepted standard for the Uralian. This was true in part

[27] M. Tolstikhina, "Carboniferous Deposits of the Central Part of the Ufa Plateau," *Trans. Central Geol. and Prospecting Inst.*, Fasc. 65 (1935), pp. 1–36.

[28] D. V. Nalivkin, "Scientific Results of the Permian Conference," *Problems of Soviet Geology*, Vol. 7, No. 7 (1938), p. 599. See translation by J. S. Williams in *Bull Amer. Assoc. Petrol. Geol.*, Vol. 22 (1938), pp. 774–79.

because it dealt with the largest and most conspicuous area of the "limestone of the Urals" and in part because it provided abundant paleontological data for comparison. *Unfortunately it was not commonly realized that the lower part of the Uralian, that is, the zone of Triticites, is not exposed in the Ufa Plateau and was not considered by Tschernyschew.*

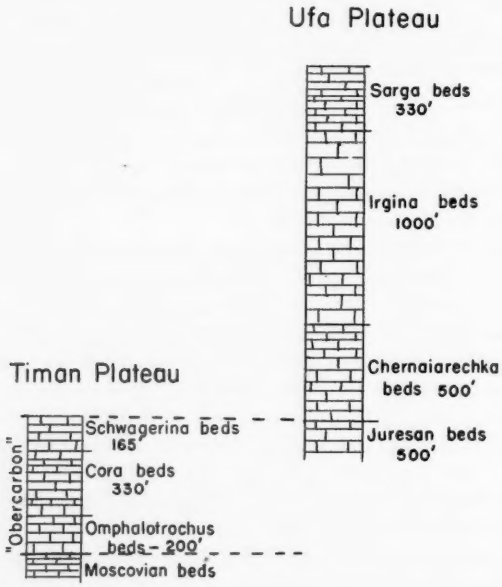


FIG. 4.—Comparison of sections studied by Tschernyschew. Succession of *Omphalotrochus*, *Cora*, and *Schwagerina* beds was determined on east flank of Timan arch. Tschernyschew later tried to apply this 3-fold subdivision to limestones of Ufa Plateau, not realizing that they are almost all younger than the Timan section.

Fredericks[29] was the first to criticize Tschernyschew's work. He concluded that "*Schwagerina*" was most abundant in the basal division and rare, if present, in the higher beds of the Ufa Plateau. He named the divisions which have since been adopted and more fully described by Tolstikhina[30] in the following descending order.

[29] Geo. Fredericks, "Le Paléozoique supérieur de l'Oural," *Ann. de la Soc. Géol. du Nord*, Vol. 53 (1928), pp. 138–71.
———, "The Upper Paleozoic of the Western Slope of the Ural," *Trans. Geol. and Prospecting Service U.S.S.R.*, Fasc. 106 (1932), pp. 1–89.

[30] *Op. cit.*

1. Sarga limestone—about 330 feet
2. Irgina limestone—about 1,000 feet
3. Chernaiarechka limestone—about 500 feet
4. Juresan limestone—about 500 feet

The later and very detailed studies by Rauser-Chernoussova of the fusulines of the Ishimbaevo oil fields, which are on the strike, south of the Ufa Plateau, served there to establish the following succession of fusuline zones, given in descending order.

1. Zone of "*Pseudofusulina*" *lutugini* [=*Schwagerina lutugini*]
2. Zone of "*Pseudofusulina*" *andersoni* [=*Schwagerina andersoni*]
3. Zone of "*Pseudofusulina*" *mölleri* [=*Schwagerina mölleri*]
4. Zone of "*Schwagerina princeps*" [=*Pseudoschwagerina*]
5. Zone of *Triticites*

The upper four of these zones can be recognized also in the limestones of the Ufa Plateau and serve still further to establish the fact that the "*Schwagerina* horizon" is the lowest instead of the highest unit in the Ufa Plateau.[31]

Tschernyschew apparently erred not only in mistaking certain facies for stratigraphic horizons, but also in failing to recognize the reefy structures that greatly thicken individual members of the sequence locally. As a result he misjudged the stratigraphic relations of his chief fossil localities. *Unfortunately, the best collections from the "Schwagerina zone" actually belonged at the base and not at the top of the sequence. Under these circumstances any generalizations based on his faunal lists must be made with extreme caution.* Because of the imposing character of Tschernyschew's paleontologic work in this great classic, many later workers, for example Schuchert[32] and Grabau,[33] have interpreted the *Uralian* almost entirely on the basis of his work. At the other extreme are those who, like Ružencev, refer all the beds of the Ufa Plateau to the Permian and restrict Uralian to the underlying Upper Carboniferous beds of the *zone of Triticites*. Hence, *unless and until the term Uralian is given a new and precise definition approved by*

[31] Scattered assertions in the literature to the effect that "*Schwagerina*" [meaning *Pseudoschwagerina*] is a facies fossil not limited to a definite horizon are believed to be invalid. Such mistaken belief may have arisen (1) from misidentification of the fusulines, (2) from reefy thickening of the *Pseudoschwagerina zone* which locally carries it above the level of younger beds as in the Shikhans described below, or (3) from misidentification of the beds in which the fusulines occur. Rauser-Chernoussova ("On Some Fusulinids of the Schwagerina Horizon, *et cetera*," *Studies Geol. Inst. Acad. Sci.* (Moscow), Vol. 7 (1938), p. 192) has recently stated that the "*Schwagerina* complex" characterizes a definite zone 600–900 feet thick in the limestone facies of the Ufa Plateau and an equivalent but thicker horizon in the "Artinsk" facies. So far as the writer can discover, there is no known instance in the U.S.S.R. of the occurrence of the genus *Pseudoschwagerina* outside this zone.

[32] C. Schuchert, "Review of the Late Paleozoic Formations and Faunas, *et cetera*," *Bull. Geol. Soc. America*, Vol. 39 (1928), pp. 769–886.

[33] A. Grabau, *The Permian of Mongolia. Natural History of Central Asia* (Amer. Mus. Nat. Hist., New York), Vol. IV (1931).

the Soviet geologists, its further use can only lead to ambiguity and confusion.

Sakmarian series.—In 1936 Ruženčev introduced for the beds of the *Pseudoschwagerina zone* the term *Sakmarian series.*[34] Although this name has not been accepted by all Soviet geologists, it seems alto-

FIG. 5.—Shikhan Tra-Tau, a reef in Sakmarian beds. Height about 900 feet above foreground. Dart marks point shown in Figure 6.

[34] V. E. Ruženčev, "New Data on the Stratigraphy of the Carboniferous and Lower Permian of the Orenburg and Aktiubinsk Districts," *Problems of Soviet Geology*, No. 6 (1936), p. 489.

This is the *Schwagerina zone* of authors. Restudy of the types of *Borelis princeps* Ehrenberg, the genotype species of *Schwagerina*, led Dunbar and Skinner to the discovery that they have deeply fluted septa, lack chomata, and are not suddenly inflated after a juvenile stage. They have, in fact, the structure for which the name *Pseudofusulina* had been introduced. Accordingly Dunbar and Skinner redefined *Schwagerina* in accordance with its genotype and introduced the name *Pseudoschwagerina* for shells of the type of *Schwagerina princeps* Möller [not Ehrenberg], that is, those having a tightly coiled juvenarium followed by rapid inflation. Accordingly,

Schwagerina (*auctoris*) becomes *Pseudoschwagerina;*

Pseudofusulina Dunbar and Skinner becomes *Schwagerina* Möller;

The "*Schwagerina* zone" of authors becomes the *Pseudoschwagerina zone.*

While most students of the fusulines have accepted this change, Rauser-Chernoussova has urged that the Rules of Nomenclature be set aside in this case and she continues to use *Schwagerina* in the old sense. The confusion resulting from the change is greatly regretted, and is aggravated by the fact that *Schwagerina* (in the new sense) occurs in the same horizon as *Pseudoschwagerina* [=*Schwagerina auctoris*] but is more extended in its stratigraphic range.

gether desirable to have such a stratigraphic name for these beds. They constitute the best known and most important key horizon in the entire Permo-Carboniferous complex and have recognized equivalents in many parts of the world and, under the name of "*Schwagerina* zone," have figured much in discussions of intercontinental correlation. Quite aside from the question as to whether they should be considered Upper Carboniferous or Lower Permian, they constitute a well defined group of strata and should be treated as a large stratigraphic unit. Although commonly included in the *Uralian*, they have never constituted more than a part of that unit.

FIG. 6.—Obscure bedding with primary dip on flank of reef at point marked in Figure 5.

Along the western flank of the Urals and in the Ufa Plateau the Sakmarian appears generally in the form of rather pure, light gray limestone with a thickness of 500–750 feet, and in this region it thickens locally because of the development of reefs or bioherms, some of which project upward into or even beyond the overlying formations. The most remarkable of these appear in the region of Sterlitamak where they rise above the plains as sharp hills, known as Shikhans. These were observed by Murchison and interpreted as sharp structural deformations. This explanation was commonly adopted by later workers until Nalivkin interpreted them as reefs. The southernmost of a group of four such hills near Sterlitamak is the Shikhan Tra-Tau. As shown in Figure 5, it appears as a conical

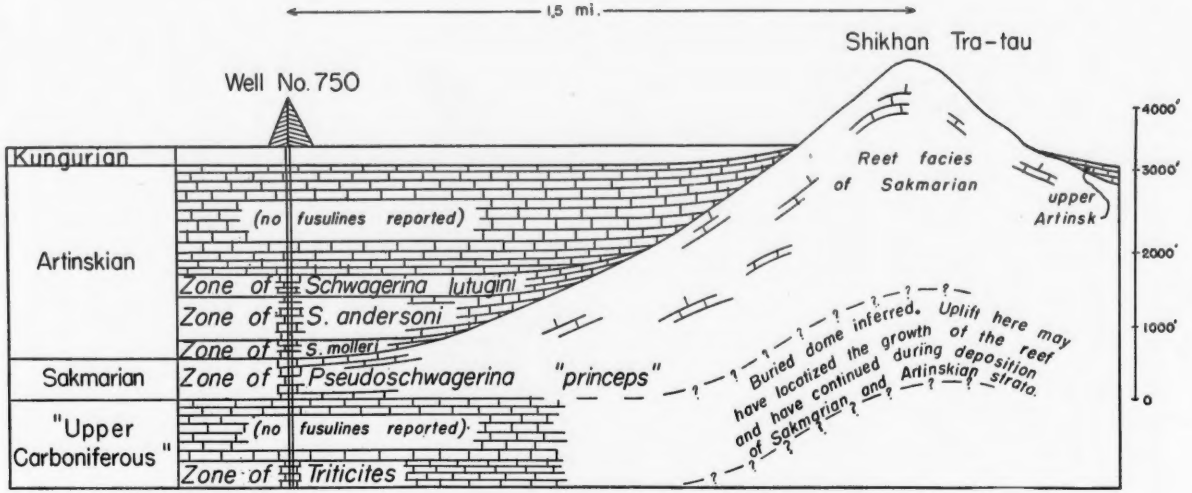


FIG. 7.—Inferred section through Shikhan Tra-Tau, showing relations of flanking Artinskian and Kungurian strata.

hill with an area at the base of about one square mile. It is richly fossiliferous and has been a famous collecting place since the days of Murchison. Bedding is very obscure, and takes the form of radially disposed talus slopes formed about the flanks of the growing bioherm (Fig. 6). The rock exposed about the base is therefore of approximately the same age as that which forms its apex. *Pseudoschwagerina* has been found near its summit and identified by Rauser-Chernoussova. Two cored wells have recently been drilled about 1.5 miles northwest of the Shikhan, and that of well No. 750 has been critically studied in comparison with the logs of about eighty other wells in the near-by Ishimbaevo oil field.[35] These data suggest the relations shown in Figure 7. If this interpretation is correct, only the apex of the reef is now exposed, its flanks being overlapped by more than 2,500 feet of Artinsk limestones. The actual overlap can be observed at only one place, however, on the southeast slope, where the upper Artinsk limestones, silty and thin-bedded, rest with obvious unconformity on the white limestone of the reef.

This unconformable overlap of Upper Artinsk limestone on the Sakmarian appears to have been one of the most convincing arguments in the minds of those who think the latter should go into the Carboniferous. But actually this apparently great break may have no more than very slight local significance, for *if it be granted that the Shikhan stood as a great reef rising above the Sakmarian sea floor, it would be unconformably overlapped in just this fashion by the younger formations even though the sea remained permanently in the region and deposition was continuous between the reefs.*

The one apparent obstacle to interpreting the Shikhan as a reef is the great height of more than 3,000 feet to which its peak rises above the level of the beds of its base in well No. 750. A reef growing so high would imply excessively great depth of water when its growth was complete. In this connection, John Emery Adams[36] has suggested the probability that a dome was forming under the reef as it grew, and that this uplift probably initiated and localized the reef growth and continued after the reef was completed and while the Artinsk limestones were being deposited.

The Shikhan Shak-Tau a few miles farther north is more elongate and appears to be part of a chain of such partially buried reefs. It also has yielded abundant *Pseudoschwagerina* and is therefore of the Sakmarian horizon. It is possible, of course, that the buried part of Tra-Tau is broader and flatter than indicated. The logs of some nearly

[35] *Guidebook Permian Excursion, Southern Part,* pp. 84–90.

[36] Personal communication.

eighty wells in the Ishimbaevo oil field, a few miles south of the Shikhans, reveal marked inequalities in the thickness of the zone of *Pseudoschwagerina* and in the depth to its upper surface. This is interpreted to be the result of similar reefy developments. In the exposures of this horizon in the Ufa Plateau similar reefy structures of smaller dimensions are exposed and have been described by Tolstikhina.[37]

The Sakmarian persists in a calcareous facies throughout the Ufa Plateau and as far eastward as the westernmost folds of the Urals. In the section along Sim River at Vavilova, for example, these limestones form part of the great fossiliferous cliff known as Kazarmeny Kamen. A rapid change in facies occurs to the east of Vavilova as shown by the section at Sim Works (see page 246 and Figure 3). Here the basal part consists of well bedded limestone alternating with beds of limestone breccia, this being followed by the great Domennaya breccia and that in turn by siltstones and shales with minor conglomerate beds. Here several hundred feet of the base of the "Artinsk" belongs to the zone of *Pseudoschwagerina* and should be classified as Sakmarian.

In the Orenburg region, according to Ružencev,[38] the Sakmarian appears as limestone in the western exposures but in the east consists of sandy argillaceous beds with interbedded conglomerates, and attains a maximum thickness of 3,000–4,000 feet.

West of the Urals the Sakmarian thins rapidly and in the Samara Bend is represented by 50–60 feet of dolomitic and gypsiferous limestone resting upon the beds with *Triticites* and succeeded by a small thickness of gypsum that may represent the Kungurian and in turn is succeeded by the Kazanian.

If present at all in the Moscow basin, the Sakmarian is represented only by the *Omphalotrochus* beds, the upper part of the Gshelian. No *Pseudoschwagerina* has been recorded from these beds, however, and Ivanov's monograph[39] on the brachiopods indicates a good many species in common with the Teguliferina beds. It appears probable, therefore, that the *Omphalotrochus* beds are part of the *zone of Triticites*.

Artinskian series.—The name Artinsk was first applied by Karpinsky[40] to a thick series of shales, sandstone, and conglomerate ex-

[37] M. Tolstikhina, "Carboniferous Deposits of the Central Part of the Ufa Plateau," *Trans. Central Geol. and Prospecting Inst.*, Fasc. 65 (1935), pp. 1–35.

[38] V. E. Ružencev, *op. cit.*, p. 506.

[39] A. P. Ivanov, "Dépôts du Carbonifère moyen et supérieur du gouvernment de Moscou," *Bull. Soc. Nat.* (Moscow), Sec. Géol., Vol. 34 (1926), pp. 133–80.

[40] A. Karpinsky, "Geologische Untersuchungen im Gouvernment Orenburg," *Verh. Min. Gesellsch.* (St. Petersbourg), Vol. IX (1874), pp. 212–310.

posed along the west flank of the Urals, as at Artinsk. These detrital beds had been seen by Murchison and mistakenly referred to the Millstone Grit, but Karpinsky showed them to be younger and thought them transitional between Carboniferous and Permian. They were later studied by several workers, among whom Krotow[41] should be mentioned for his monograph which lists 293 species of fossils from these beds. He considered them to be Upper Carboniferous. But subsequent study of the ammonites led Karpinsky to conclude that they belong in the Permian,[42] and this assignment has since come to be generally accepted.

As proposed and long used, the name Artinskian applied to a facies—a great deposit of shales, siltstone, and sandstones limited to a narrow belt along the west flank of the Urals. These deposits vary rapidly in lithology and in thickness and bear marine fossils at certain zones and fossil plants at others. Members of the Permian Excursion studied a well exposed section of these beds at Sim Works exceeding 4,500 feet in thickness. This locality is on the strike not far south of Artinsk. They observed another great section in the bluffs of Kossva River near Gubaka where these shales, sandstones, and conglomerates exceed 1,400 feet in thickness. This is far to the north of Artinsk and northeast of Perm. In the belt southeast of Perm, along the railway between Kuzino and Perm, Kruglov and Tolstikhina have worked out a succession of Artinskian beds ranging from 4,800 to more than 6,000 feet in thickness.[43]

Although long considered younger than the limestones of the Ufa Plateau, *these detrital deposits are now believed by an increasing number of Soviet geologists to be equivalent to a part of these limestones*, as indicated in Figure 2. Leaders in bringing out this relationship have been Noinsky, D. V. Nalivkin, Gerassimov, and Ossipov. Equivalence of the limestone and detrital facies was not seen earlier for several reasons, chiefly (1) lack of adequate exposures in critical areas of transition and (2) a general change in the faunal facies resulting from the change in lithologic facies. Evidence for the correlation has grown rapidly as modern faunal studies have increased. For example, Rauser-Chernoussova[44] has found that the "zone of *Schwagerina*"

[41] P. Krotow, "Artinske Etage, *Geologisch-Paleontologische Monographie des Sandsteins von Artinsk*," *Proc. Soc. Nat. Kazan University*, Vol. 13, No. 5 (1885), pp. 1–314, Pls. 1–4.

[42] A. Karpinsky, "Ueber die Ammoneen der Artinsk-Stufe," *Mem. Acad. Sci.* (St. Petersbourg), 7th Ser., Vol. 37, No. 2 (1889).

[43] *Guidebook of the Permian Excursion, Northern Part* (1937), pp. 34–44.

[44] D. Rauser-Chernoussova, "On Some Fusulinids of the Schwagerina Horizon (the Group of *Pseudofusulina uralica* Krotow)," *Studies Geol. Inst. Acad. Sci.* (Moscow), Vol. 7 (1938), pp. 192.

FIG. 8.—Karpinsky's map of Artinskian deposits (1889, p. 3, Fig. 1).

(characterized not by a single genus or species, but by a coterie of species which she calls the "*Schwagerina* complex") is a definite stratigraphic horizon "both in the limestone facies of 'the Upper Carboniferous' and in the 'Artinskian' deposits which we therefore

consider synchronous ones." This establishes the fact that the Sakmarian horizon occurs in a limestone facies in the plateau and in a detrital facies in the geosyncline. In the former region the Sakmarian is succeeded by limestones which reach a thickness of nearly 3,000 feet in the Sterlitamak area, where they are directly succeeded by Kungurian beds. These limestones are divisible into the zones of *"Pseudofusulina" mölleri, andersoni,* and *lutugini,* as indicated in Figure 2. But in the geosyncline the Sakmarian is succeeded directly by a great thickness of typical Artinsk detritals which, in turn, are followed directly by Kungurian. Being mutually exclusive, the limestones of the plateau and the detritals of the geosyncline are equivalent, or else a profound unconformity separates them, and the limestones have been eroded from the geosyncline and the Artinsk detritals overlap abruptly against their eroded edges. The fusuline evidence cited above shows conclusively that the lower part of the Artinsk facies grades westward into limestone, and the general field relations would strongly imply that the succeeding horizons do likewise. In addition Gerassimov[45] has discovered sixteen species of ammonites in the limestone facies about the Shikhans Tra-Tau, Schak-Tau, Kush-Tau, and Jurak-Tau which are closely allied to the well known Artinsk ammonites and which have convinced him of the Permian age of these limestones, even those of the *Pseudoschwagerina* zone. Furthermore, he records the presence of the very distinctive shark, *Helicoprion bessonowi,* both in the Artinsk facies on Sylva River and in the limestone facies at upper Tschussovaya village.[46]

In the Ufa Plateau, the limestones have been divided into four named formations, as explained on page 252. Their microfaunas have been more carefully studied in the well cores of the Sterlitamak region which lies down the strike on the south. There fusuline faunal zones have been established that may be related to the formations of the Ufa Plateau, as follows.

Sarga beds	Zone of *"Pseudofusulina"* [*Schwagerina*] *lutugini*
Irgina beds	
Chernaiarechka beds	Zone of *"Pseudofusulina"* [*Schwagerina*] *andersoni*
Juresan beds	Zones of *"Pseudofusulina"* [*Schwagerina*] *mölleri* and *"Schwagerina"* [*Pseudoschwagerina*] *"princeps"*

This correlation is based in part on personal conversations in the field. See, also, Nalivkin, D. V., "Scientific Results of the Permian Conference," p. 602.

[45] N. P. Gerassimov, "Ural Division of the Permian System," *Science Notes* (Kazan University), Vol. 97, Nos. 3–4 (1937), pp. 3–68.

[46] *Op. cit.*, p. 67.

Like the underlying Sakmarian limestone, the Artinsk limestones of the longitude of the Ufa Plateau display local reefy facies which commonly exceed in thickness the non-reefy equivalent. Members of the Permian Excursion studied such reefs in the Sarga beds in the bluffs of the Sylva River between Kishert and Kungur.

Kungurian series.—This is the great salt-bearing series, typically developed about the town of Kungur and better known from bore holes. It varies greatly in lithology and thickness. During its deposition the Permian sea was much restricted, occupying a rather narrow, rapidly deepening trough with its axis running through Kungur and Solikamsk. Along this axis the thickness ranges from about 2,000 feet to 4,500 feet. Perhaps the thickest and best studied development is in the vicinity of Solikamsk where it includes one of the world's greatest potash salt deposits. There it begins with anhydrite and shale interbedded with rock salt for a total thickness of more than 1,200 feet. This basal member is succeeded by rock salt ranging from about 400 to 1,300 feet thick which in turn is followed by the chief deposits of potash salts, first a bed of sylvite and then one of carnallite. An upper bed of halite follows and is overlain by more gypsum and anhydrite and finally by gray clays and marly limestone.

Tolstikhina[47] has shown that this series grades eastward into continental lacustrine and lagoonal beds of Artinsk facies; also, that there are regional changes of facies from south to north, with continental redbeds predominating in the latitude of Ufa, with lagoonal and marine beds including limestones and dolomites in the latitude of Kungur, and with chiefly evaporites in the latitude of Solikamsk, while farther to the north in the Pechora River region the deposits are continental and coal-bearing.

Kazanian series.—This series was named by Krotow for the exposures about Kazan, which is out in the center of the Russian platform. In this region it is a group of limestones between 400 and 500 feet thick, divisible into two well marked faunal zones. The lower Kazanian, or "*Spirifer* beds," is characterized by a brachiopod fauna in which *Spirifer rugulatus* and *Linoproductus hemisphericus* predominate; the upper Kazanian, or "*Conchifera* beds," is characterized by a molluscan fauna of gastropods and pelecypods.

This calcareous facies of the Kazanian extends westward with gradually diminishing thickness, but no marked change of facies, into the Oka-Tsna uplift within 250 kilometers of Moscow. But not far east of Kazan, and of the Samara Bend, it begins to change facies, grading first into gray marine shales, then into gray siltstones and

[47] "Abstracts of Papers," *Seventeenth Inter. Geol. Congress* (1937), p. 98.

shales with non-marine zones bearing plant fossils, and finally into the bright red cupriferous sandstones on which the city of Perm stands. From Perm to near Kazan, the Kama Valley is cut in this horizon and members of the Permian Excursion had an exceptional opportunity to see this gradual and complete transition from the red continental facies to the white limestones of Kazan as we followed the course of the river for 3 days with numerous stops for collecting. We also saw the transitional beds in the vicinity of Ufa where the term Ufimian has been applied to the non-marine facies.

Because the Kazanian limestones have a fairly uniform thickness over a large area in the Russian platform and are easily recognized by their faunas, they form an important key horizon in any study of the regional classification of the Permian rocks. The fossil plants found by Murchison in the non-marine facies constituted one of his chief reasons for creating a distinct Permian system. There is also an important zone of fossil reptiles in this facies.

It may be noted that the Kazanian beds spread farther to the west over the platform than do either the Artinskian or the Kungurian, and that they do not thicken so markedly in the geosynclinal area.

Tartarian series.—This series was named by Nikitin, who thought it to be Triassic; it includes only continental deposits of the redbed facies. These occupy a great area of the central part of the Permian basin but are not of a great thickness. Murchison referred them to the Permian but seemed to have some premonition that part of these redbeds might belong to the Triassic. The beds have yielded locally a large number of vertebrate fossils. These are being studied by Efremov,[48] who recognizes in the upper part of the series, as currently defined, two distinct zones of Triassic age. A comprehensive study of the stratigraphy of the Tartarian has been carried on by Mazarovitch,[49] who recognizes seven divisions of these redbeds, of which the lower two only (Urzhumian and Sarmian) are Permian, the upper five being Triassic. In fact, the boundary lies in the upper part of the Sarmian division. The Urzhumian division is characterized by a Paleosaurian fauna and the lower Sarmian by Permian stegocephalians of the Pareiosauridae. The highest part of the Sarmian, on the contrary, contains a fauna of Triassic Stegocephalia (Capitosauridae and Trematosauridae).

[48] "Abstracts of Papers," *Seventeenth Inter. Geol. Congress* (1937), p. 91.

[49] A. N. Mazarovitch, "Dépôts continentaux du permien supérieur et du trias inférieur dans la Platforme Russe," *Abstracts of Papers Seventeenth Inter. Geol. Congress* (1937), p. 100.

Either the Tartarian must be greatly restricted and redefined or else it must be abandoned. Mazarovitch advocates rejection of the name because it has not been a natural unit, but he has not proposed a single inclusive term for the Permian portion.

Recapitulation.—In Figure 2 and in the foregoing discussion, the writer has tried to present, as objectively as possible, the stratigraphic relations of the Middle and Upper Carboniferous and the Permian strata of the Permian basin of Russia. The picture is oversimplified, for the region is vast and the facies changes complex. Undoubtedly there is much in the Russian literature that is unknown to the present writer; and certainly there are many features that require more investigation before the final classification of these rocks can be achieved although during the last two decades the Soviet geologists have made enormous strides in laying a firm foundation for that attempt.

A single cross section can not do justice to the complexity of an area so great as the Permian basin. Nevertheless, the writer believes that it represents correctly the major features of the stratigraphy and would be largely duplicated by other sections either north or south which crossed the Russian platform and the geosyncline. This section, at least, is historically significant because it represents the area on which Murchison largely based his Permian system.

Among the questions pressing for information not available to the writer are the following. (1) How much of the *zone of Triticites* is represented by the Gshelian? (2) Is the upper part missing generally in the Moscow basin? (3) How far west of the Samara Bend does the *zone of Pseudoschwagerina* extend, and does it thin by the progressive disappearance of the upper or the lower beds, or both? (4) How important regionally is the break represented at the base of the Sakmarian at Sim Works? (5) What particular zones in the detrital facies of the Artinskian correlate with the recognized zones in the limestones of the Ufa Plateau?

It should be pointed out also that the lower limit of the "Artinsk" facies does not everywhere coincide with the base of the Sakmarian as represented in Figure 2. In the Orenburg region, which lies at the southeast corner of the Permian area, the entire section of the Carboniferous and Permian is thicker and in the eastern part of that district is chiefly detrital. Karpinsky originally recognized that the lower part of his Artinsk in this region was older than the shales and sandstones at Artinsk, and Ruženčev[50] has demonstrated, after several years of study in the region, and after relocating Karpinsky's ammonite localities, that the Artinsk facies goes as low as the Middle

[50] E. V. Ruženčev, "On the Stratigraphy of the Artinskian Stage of the Orenburg Region in the Urals," *Problems of Soviet Geology*, Vol. 5 (1935), pp. 657–71.

Carboniferous. He also concluded that an important movement occurred east of the Orenburg region just before the Upper Carboniferous. Accordingly, he greatly restricts the Artinskian in this region and proposes to define it on faunal grounds, limiting it to beds above the *zone of Pseudoschwagerina*, regardless of the facies.

Also, to the east of the Ufa Plateau, in the region of Kussinisky and Niazepetrovsk, the "Artinsk" rests upon beds as low as the Lower Carboniferous.[51] But here, due to the lack of faunal evidence, it is not known what horizon is actually represented by the "Artinsk" facies.

COMPARISON WITH AMERICA AND ORIENT

General statement.—The Permian must be interpreted in harmony with the classical type region above discussed; but its validity as a system, and its natural limits, may best be determined by comparison with the records in other parts of the world, if it is to be a "major unit of world-wide significance." In such comparison the greatest importance attaches to the major basins of *marine* deposits of late Paleozoic age. Although continental formations, bearing plants and vertebrates, provide an important supplement, the marine record still remains the chief standard for classification.

Outside of the U. S. S. R., the greatest areas of marine Permian rocks are those of South China (extending into Indo-China) and of southwestern United States. These are of major importance because each is a basin of large dimensions bearing a thick and relatively complete marine record so free of structural disturbance that the natural succession is clear. These and the type region of the Permian constitute three vast and widely separated basins of late Paleozoic deposition, representing three of the continents. The limited space here available will be devoted chiefly to them.

The other best known areas of Permian rocks have serious shortcomings of one sort or another. In Japan, for example, the structure is so complicated that the succession of formations can be determined only by faunal correlation with other areas. The Salt Range section begins with a horizon as young as the Artinsk and its relations to the Carboniferous are not shown; moreover, its faunas are curiously restricted so that fusulines are confined to the lower part and ammonites to the upper. The famous section of the Carnic Alps is apparently much more nearly complete, but the region is structurally complex and its faunas are as yet only partly studied. So far as known to the writer, however, none of these regions presents any features out of harmony with the classification given in Figure 9, and recent work by Heritsch in the Carnic Alps fits well into this scheme.

[51] D. V. Nalivkin, "The Ufa Amphitheatre," *Guidebook of the Permian Excursion Seventeenth Inter. Geol. Congress, Northern Part* (1937), pp. 21, 22.

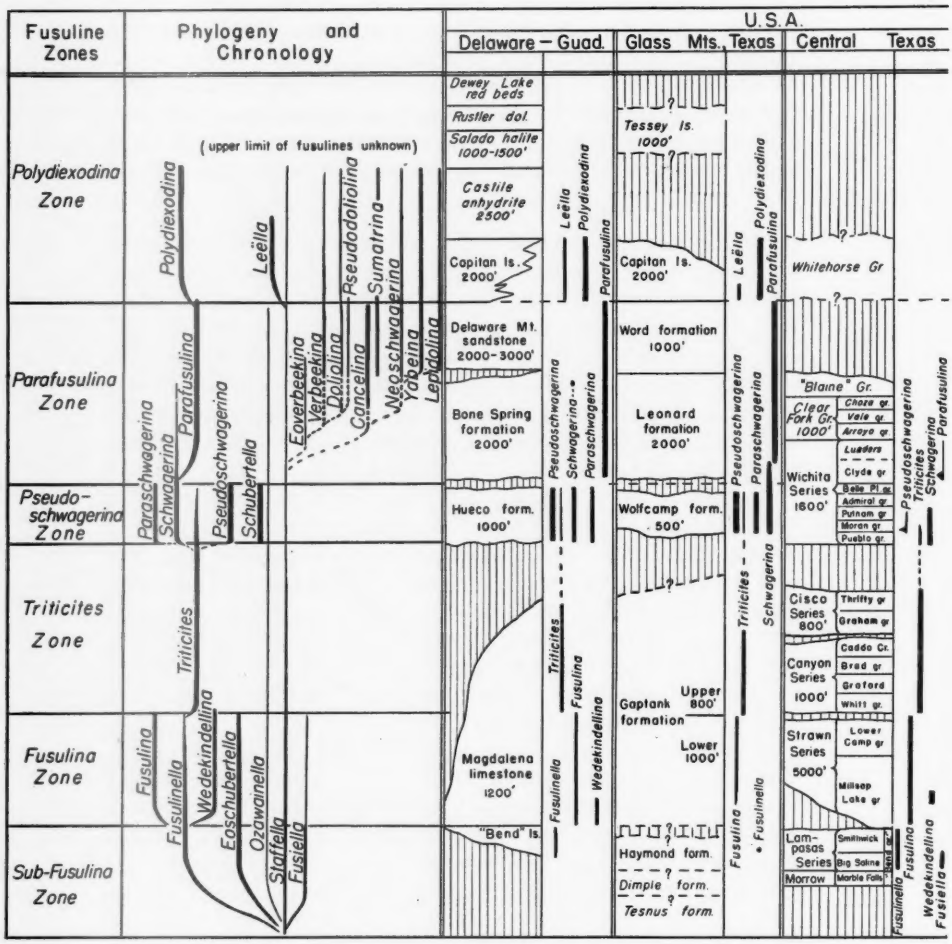
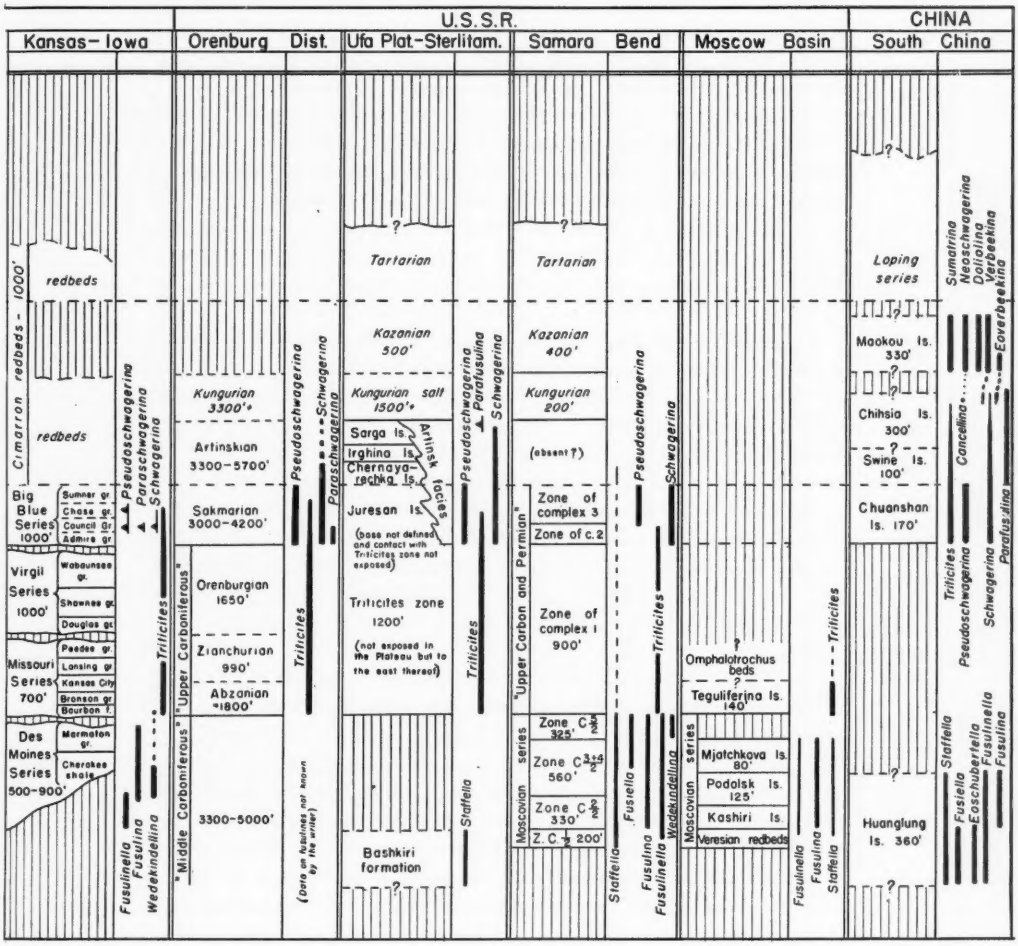


FIG. 9.—Correlation chart of Middle and Upper Carboniferous and Permian formations in Pennsylvanian classification is revised in accordance with recent work



U.S.S.R., United States, and South China, based chiefly on fusuline zones. In column for central Texas, of M. G. Cheney (*Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 1, January, 1940).

In Russia, China, and southwestern United States fusulines are very abundant and widely distributed in both Carboniferous and Permian rocks, and serve as a very useful basis of zonation and correlation. The following comparisons are thus arranged partly because the fusulines provide the most generally available common denominator and partly because this evidence is most familiar to the writer.

It is fully realized that other groups of fossils are important and must be taken into consideration in the final correlation and classification of the Permian rocks, but space is not available here to analyze all these faunas. So far as the writer is aware, the other invertebrate groups would confirm the correlations indicated. According to recent studies by Miller, the ammonites strongly confirm the results obtained from a study of the fusulines, without any conflicting data.

As indicated in Figure 9, a series of fusuline zones can be recognized in the several sections presented and these invariably appear in the same order of succession and so afford a basis for international correlation. The range of each fusuline genus is graphically shown beside each columnar section. The phylogeny of the fusulines represented at the left of this chart is being discussed elsewhere.[52]

In all three great regions represented in the chart the upper part of the Permian goes over into non-marine and commonly unfossiliferous deposits. Such units, having no fusulines, are indicated in lighter and oblique type, and their correlation is inferred from other lines of evidence and, in part, is very tentative.

PRE-PERMIAN FUSULINE ZONES

The lower three fusuline zones of this chart represent the Pennsylvanian system as it is generally recognized in the United States. The lower two of these are now commonly termed Middle Carboniferous by European geologists. For our present purpose they might be omitted from consideration except for the fact that the *Fusulina zone* constitutes an extremely widely spread and easily identified key horizon below the formations that are under controversy.

The *Fusulina zone*, well represented by the Des Moines series of the Mid-Continent region and by the Strawn group in north-central Texas, is characterized by the predominance of species of the genus *Fusulina*. Its upper limit is sharply defined by the abrupt disappearance of this genus and the incursion of primitive species of the genus *Triticites*. *Fusulinella* and *Wedekindellina* both occur in this zone but

[52] Carl O. Dunbar, "Zonation and Correlation of the Late Paleozoic Formations on the Basis of the Fusulinidae," *Proc. Seventeenth Inter. Geol. Congress.* (In press.)

their range shows some discordances in different provinces. In the United States, *Wedekindellina* marks a very distinct subzone in the lower half of the *Fusulina zone* that can be recognized all the way from Illinois to New Mexico and northward into Wyoming; the genus is limited to this range with the single known exception of a recurrence in the base of the *Triticites zone* near Kansas City. In the U. S. S. R., however, it is restricted to an equally definite subzone at the top of the Moscovian—one that is recognized in the Samara Bend, along the western slope of the Urals, and in the Don Basin. The genus apparently originated in America and later migrated to Europe; the recurrent American species, *W. ultimata*, agrees more closely than any of the lower species with the common Russian forms *W. uralica* and *W. doutkevitchi*.

The *Triticites zone* corresponds to the upper part of the Pennsylvanian system and is characterized by many species of the genus *Triticites* and by the absence of nearly all other types of fusulines. Some primitive forms, such as *Staffella* and *Ozawainella*, range up through this zone and into the Permian and are locally abundant, but *Fusulina* and *Fusulinella* are absent and, with the single exception already noted, *Wedekindellina* is unknown.

This zone is about 1,000 feet thick in the northern Mid-Continent region, where it includes the Missouri and Virgil series, and about 1,700 feet in central Texas, where it includes the Canyon and Cisco groups. A distinct evolution is evident within this zone. The early species are all small and slender and have relatively thin walls. Gibbous forms, such as *T. plummeri*, appear first in the lower Cisco and in the lower Virgil, and in the upper half of the Virgil group the prolific tribe of *T. ventricosus* develops species much larger than any below.

The *Triticites zone* constitutes the lower part of the "Uralian" of the U. S. S. R., as shown in Figures 2 and 9 but there is still some question as to how completely it is represented. In the Moscow basin it is apparent that only the lower part is preserved. In the Samara Bend, about 900 feet of strata belong to this zone, according to the very important recent work of Rauser-Chernoussova (1938). The fact that the species of *T. jigulensis* and *T. volgensis* pass upward from these beds into the overlying *Pseudoschwagerina zone* would suggest that no important hiatus intervenes and that the upper part of the *Triticites zone* is represented here. In the Orenburg region, the *Triticites zone*, according to Ružencev (1937), attains a thickness of over 4,400 feet and is divisible into three series, the Abzanian, the Zianchurian, and the Orenburgian, named in ascending order. The fusulines were studied and identified by Rauser-Chernoussova and, as

represented on Plate 1 of Ruženčev's work, show that fifteen species pass upward into the basal division of the Sakmarian, though all but three of these are based on a single occurrence in the Sakmarian.

The character and distribution of this zone west of the Urals have already been discussed.

In South China, the *Triticites zone* is almost, if not completely, lacking and the Chuanshan limestone with *Pseudoschwagerina* and *Schwagerina* rests disconformably on the Huanglung limestone. The genus *Triticites* is represented, of course, in the Chuanshan limestone, as it commonly is in the *Pseudoschwagerina zone*, but the zone marked by *Triticites* alone is lacking. This great break is regional in its extent for the same relation holds in Indo-China, as shown by Fromaget.[53] His horizons 2 and 3 are clearly Moscovian in age but 4 to 7 have the complex of the *Pseudoschwagerina zone*. Moreover, he states (pp. 24–26) that in northern Indo-China there was great igneous activity between the deposition of zone 2 and of those containing *Pseudoschwagerina*.

PERMIAN FUSULINE ZONES

The Pseudoschwagerina zone.—This is perhaps the most useful of all the zones for correlation, since it includes a large and very distinctive complex of species and is well developed in so many parts of the world. The genera *Pseudoschwagerina* and *Paraschwagerina* are exclusively confined to it in all the regions represented on our chart. With these goes a coterie of large species of *Schwagerina* (see Rauser-Chernoussova, 1938[54]). It also includes the last straggling species of *Triticites*.

This zone includes the Hueco limestone (restricted) of extreme west Texas, the Wolfcamp formation of the Glass Mountains, the Sakmarian of the Orenburg region in the U. S. S. R., and equivalent strata widely distributed west of the Urals. As Rauser-Chernoussova has shown,[54] it characterizes a definite zone 600–900 feet thick in the limestone facies of the Ufa Plateau and an equivalent zone up to 3,000 feet thick in the detrital "Artinsk" facies farther east. This zone also includes the Chuanshan limestone of South China and part, if not all, of the Taiyuan formation of North China. In the northern Mid-Continent region of the U. S. A., fusulines are restricted by the facies, but characteristic species of *Pseudoschwagerina* and *Schwagerina* are

[53] J. Fromaget, "L'Anthrocolithique en Indochine après la Regression Moscovienne, ses Transgressions et sa Stratigraphie," *Bull. Serv. Géol. Indochine*, Vol. 19, Fasc. 2 (1931), pp. 7–44.

[54] "On Some Fusulinids of the *Schwagerina* Horizon, *et cetera*," *Studies Geol. Inst. Acad. Sci.* (Moscow), Vol. 7 (1938), p. 192.

present in zones in the lower part of the Wichita group of central Texas and *Paraschwagerina* and *Schwagerina* occur in the Council Grove group of the Big Blue series in southern Kansas, while two common Wolfcamp species of *Pseudoschwagerina* recur in the Chase group of this series.

Parafusulina zone.—This zone is especially well developed in west Texas and New Mexico where it includes beds 3,000–4,000 feet thick. Here it is marked almost exclusively by species of *Parafusulina*. Some beds are rich in *Staffella*, and a species of *Schubertella* is locally common at one horizon. *Schwagerina* is commonly replaced by *Parafusulina*, though one large species, *S. setum*, is abundant in the upper part of the Bone Spring limestone. Neither *Pseudoschwagerina* nor *Paraschwagerina* has ever been found in this zone in America.

In central Texas and the northern Mid-Continent area the equivalent strata are chiefly redbeds, and fusulines are completely lacking or at least unknown in the outcrops. However, a core in the Big Lake field in Reagan County, Texas, yielded a long slender species of Word type from the Texon "pay sand" near the top of the "Big lime."

In the U. S. S. R., the Artinskian (as restricted by Ružencev) belongs here. As indicated in Figure 2, this includes approximately 3,400 feet of limestones overlying the *Pseudoschwagerina zone* in the Ufa Plateau, and the equivalent detrital beds of "Artinsk" facies, but it does not include the lower part of the beds of Artinsk facies (for example, division A of the Artinsk at Sim Works) which is Sakmarian. The fusuline evolution is somewhat more retarded here than in the Leonard formation of Texas, and slender species of *Schwagerina* such as *S. mölleri*, *S. andersoni*, and *S. lutugini*, persist. The latter closely approaches the evolutionary stage of *Parafusulina* and in its upper range is associated with *Parafusulina tastubensis* Vissarionova.

Since the overlying beds bear no fusulines we have no check of the upper limit of the *Parafusulina zone* in the Ural region. It appears not to be represented at the Samara Bend or farther west.

In South China the Swine and Chihsia limestones are both characterized by species of *Parafusulina*, along with numerous species of *Schwagerina*. *Triticites* runs up into the base of the Chihsia but is uncommon above the Swine. *Parafusulina*, on the contrary, is represented by a few species in the Swine and is dominant in the Chihsia. Here the genus *Schwagerina* perists above the *Pseudoschwagerina zone*, though with dwindling numbers, and the transition to the *Parafusulina zone* is more gradual than in America.

The fauna of the Maokou limestone is of great importance but has not yet been published. It includes a complex of species of the Ver-

beekininae and the Neoschwagerininae, especially of the genera *Verbeekina*, *Doliolina*, *Neoschwagerina*, and *Sumatrina*. Since this very distinctive assemblage occurs with *Parafusulina* in Japan and Indo-China, we may assume that the Maokou limestone is in the *Parafusulina zone*, probably in its upper part. It is particularly significant that these subfamilies of the oriental fusulines are represented only sparingly in the Chihsia limestone and even so by the most primitive representatives, namely *Eoverbeekina*, *Cancellina*, and a single species of *Pseudodoliolina* and two of *Verbeekina*. The primitive character of these representatives indicates quite definitely that the Neoschwagerine complex of the Maokou limestone is actually younger than the Chihsia limestone.

There is good evidence through the ammonites that the complex found in the Maokou, which is that of the Crimea and of the Sosio beds in Italy, is of Word age.[55]

Unfortunately, the upper range of the oriental fusuline genera is not indicated in South China. The Loping series is chiefly non-marine and the absence of fusulines is doubtless due to the facies. That they range up into the *Polydiexodina zone* is indicated by collections of the Indian Geological Survey now under study by the writer. It is possible to set a fairly definite lower limit to their range at about the middle of the *Parafusulina zone*. This would be above the highest fusuline zone of the Artinsk. If such fusulines had reached America they would probably occur first in the Word. That *Neoschwagerina* does appear at this horizon in British Columbia is suggested by the fact that *N. columbiana* occurs in the Cache Creek series at Marble Canyon[56] and that Miller and Warren[57] found in the upper part of the same series near Kamloops, B. C., a *Propinacoceras* (*P. americanum*) very similar to *P. beyrichi* of the Sosio beds of Italy, which carry the fusuline complex of the Maokou limestone. Unfortunately, it is not known how near the horizon of *N. columbiana* lies to that of the ammonite.

Polydiexodina zone.—This is well marked in western Texas and New Mexico, and in the Las Delicias region in Mexico. It includes the whole of the Capitan limestone and its equivalent, the upper division of the Delaware Mountain sandstone of west Texas. Careful field work has shown that the boundary between this and the *Para-*

[55] A. K. Miller, "Age of the Permian Limestones of Sicily," *Amer. Jour. Sci.*, Vol. 26 (1933), pp. 409–27.

[56] C. O. Dunbar, "*Neoschwagerina* in the Permian Faunas of British Columbia," *Trans. Roy. Soc. Canada*, Vol. 26 (1932), pp. 45–49.

[57] A. K. Miller and P. S. Warren, "A *Propinacoceras* from North America," *Amer. Jour. Sci.*, Vol. 26 (1933), pp. 295–99.

fusulina zone is quite independent of the facies and lies in a series probably unbroken. The change from *Parafusulina* to *Polydiexodina* is chiefly one of the opening of supplementary tunnels. In addition, there is a tendency for closer coiling, a thinning of the wall, and other minor changes.

As the Capitan is succeeded by anhydrite and salt and redbeds, we have no evidence in Texas to show what the upper limit of *Polydiexodina* would be.

Polydiexodina is not present in the standard section for South China because the appropriate horizon is in a non-marine facies, but the genus is present elsewhere in the Oriental realm. A species was described by Kahler from Persia and another is in the collections of the Indian Geological Survey from Afghanistan. Also, the form described by Diener as *Fusulina elongata* from the northern Shan States is apparently a *Polydiexodina*.

BASE OF PERMIAN

Historical review.—The original Permian included only the beds now embraced in the Kungurian, Kazanian, and Tartarian series. To anyone familiar with the region, Murchison's discussion will leave no doubt that he considered his new system to begin with the dolomites and anhydrite at the base of the Kungurian. The "grits of Artinsk" he mistakenly correlated with the Millstone Grit which underlies the Coal Measures of Great Britain, and the limestones of the Sterlitamak region and the Ufa Plateau he regarded as Upper Carboniferous.

Murchison's criterion for a distinct system was largely biologic, for he stated:

> though these deposits are of very varied mineral aspect, and consist of grits, sandstones, marls, conglomerates and limestone, sometimes inclosing great masses of gypsum and rock-salt, and are also much impregnated with copper, and occasionally with sulphur, yet *the whole group is characterized by one type only of animal and vegetable life.*[58]

One is a little dismayed to read further that this "one type only" included 166 species and embraced marine invertebrates, fishes, and reptiles, to say nothing of the land plants!

Murchison was impressed by certain of the fossil plants, and especially by the fossil reptiles; but it must be noted that his list of 166 species includes many forms found in the British Isles only or in Germany. While he established the system in "Permia," it is clear from his discussion that the fossils of the "Magnesian limestone" of

[58] R. I. Murchison, E. DeVerneuil, and A. von Keyserling, *The Geology of Russia and the Ural Mountains*, Vol. 1 (1845), p. 138.

England and the "Rothliegende" of Germany afforded much of his biologic evidence for a distinct system, and one can hardly avoid the suspicion that he had considered erecting a system to embrace these reptile-bearing strata before he set out for Russia. It must also be admitted that his analysis of the invertebrate faunas had no real significance in the light of modern knowledge of the faunas.

The Artinskian was added to the Permian by Karpinsky[59] in 1889, as a result of his monographic study of the ammonites. Although no ammonites occur in the Kungurian, Kazanian, or Tartarian beds, they were by this time known in other parts of the world in beds accepted as undoubtedly Permian. While Karpinsky recognized that the Artinsk ammonites had their source in Upper Carboniferous types, and while he considered them transitional to the more advanced types of the admitted Permian, he stated his opinion that if either the Carboniferous or the Permian system was to be extended to embrace these transition beds, it should be the Permian, because the greater faunal change occurred below the Artinsk. This opinion prevailed and the Artinskian has since been generally accepted as Permian.

On the contrary, Tschernyschew in his great monograph of the brachiopods in the limestone facies of the Ufa Plateau, *assumed* the Carboniferous age of all these beds. As explained above, he included beds below the Sakmarian horizon in the Timan region and all the limestones above it in the Ufa Plateau and treated them all as a unit. Seeing among these brachiopods numerous species identical with or similar to those of the Trogkofel limestone of the Alps, the Sosio beds of Palermo, and the *Productus* limestone of the Salt Range, he favored placing all these, in whole or in part, in the Carboniferous. In 1924, however, Beede[60] pointed out that, although Tschernyschew's conclusions as to the age of the "*Schwagerina* horizon" in Russia were still accepted, *all these other beds with which he made correlations had come to be generally accepted as Permian*, that is, as Artinskian or younger. Accordingly, Beede made a critical analysis of Tschernyschew's faunal discussion, pointed out that he had mixed undoubted Carboniferous (the *Omphalotrochus* and *Cora* beds of the Timan Plateau) with younger faunas, and that the latter included numerous genera otherwise restricted to the Permian. In this connection it is important to reiterate that some of Tschernyschew's largest and best

[59] A. Karpinsky, "Ueber die Ammoneen der Artinsk-Stufe," *Mem. Acad. Sci.* (St. Petersbourg), 7th Ser., Vol. 37, No. 2 (1889).

[60] J. W. Beede and H. T. Kniker, "Species of the Genus *Schwagerina* and Their Stratigraphic Significance," *Univ. Texas Bull. 2433* (1924), pp. 60–71.

collections (for example, that from Mount Tastuba) were really from the *Pseudoschwagerina zone* and not from the higher beds.

Subsequent studies have clearly established the fact that the Sosio beds correlate with the Word of Texas,[61] that the Trogkofel limestone is of Leonard age,[62] and that the *Productus* limestone is not older than Leonard;[63] and all now agree that the Leonard of America correlates with the Artinsk of Russia and the Word is still higher.[64] In short, the chief foreign deposits with which Tschernyschew correlated his Upper Carboniferous can now be correlated directly with Artinskian deposits which are generally accepted as Permian in its type area, or indirectly, through the American section, with deposits even higher than the Artinsk.

Gradually, most American stratigraphers have come to accept the Sakmarian and its equivalents as Lower Permian, and this usage is officially adopted in mapping by most of the states in which Permian rocks are important, notably Texas, New Mexico, Oklahoma, Kansas, and Nebraska, and, in part at least, by the U. S. Geological Survey, which now classifies the Wolfcamp as Permian (see *U. S. Geol. Survey Prof. Paper 187*, 1937). This boundary is also adopted by several prominent stratigraphers outside of North America, notably Grabau in China and Heritsch in the Carnic Alps.

Schuchert[65] and Grabau[66] have both been influential in shifting the base of the Permian below the *Pseudoschwagerina zone*, but both had to accept Tschernyschew's work at its face value, and so fell into the error of including in the Permian the *Omphalotrochus* and the *Cora zones* of the Timan Plateau, which are undoubtedly Carboniferous.

Among the Soviet geologists there is, at present, a wide difference of opinion as to where the base of the Permian should be drawn in its

[61] A. K. Miller, "Age of the Permian Limestones of Sicily," *Amer. Jour. Sci.*, Vol. 26 (1933), pp. 409–27.

[62] F. Heritsch, "Die Stratigraphie von Oberkarbon und Perm in den Karnischen Alpen," *Geol. Gesell.* (Wien), Bd. 26 (1933), pp. 162–90.

[63] Carl O. Dunbar, "Stratigraphic Significance of the Fusulinids of the Lower Productus Limestone of the Salt Range," *Records Geol. Survey India*, Vol. 66 (1933), pp. 405–13.

[64] A. K. Miller, "Comparison of Permian Ammonoid Zones of Soviet Russia with Those of North America," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22 (1938), pp. 1014–19. Also F. Heritsch, *op. cit.*

V. E. Ružencev, "Ammonoids of the Sakmarian Stage and Their Stratigraphic Significance," *Problems of Paleontology*, Vol. IV (1938), pp. 203–85, Pls. I–VII.

[65] C. Schuchert, "Review of the Late Paleozoic Formations and Faunas, *et cetera*, *Bull. Geol. Soc. America*, Vol. 39 (1928), pp. 769–886.

[66] A. Grabau, *The Permian of Mongolia. Natural History of Central Asia* (Amer. Mus. Nat. Hist., New York), Vol. IV (1931).

type region. This is clearly indicated in the published account of a conference of leading Soviet specialists held in advance of the Seventeenth International Geological Congress,[67] and by the abstracts of the papers presented before the Permian sessions of the Congress.[68] Thus, Nalivkin and Ružencev advocate placing it below the Sakmarian, Licharev and Rauser-Chernoussova just above the Sakmarian, and Gorsky, Tolstikhina, and Nikiferova at a higher horizon, that is, at the base of the *Schwagerina lutugini* zone.

From this it may be inferred either (1) that in its type region the Permian is not separated from the Carboniferous by any profound or widely recognizable break, faunal or physical, or (2) that the stratigraphic relations are still very imperfectly known. Both inferences are probably justified. The region is vast, and until recently had received scant critical study. The fine work done by Soviet geologists during the last 15 years serves to emphasize how imperfectly the stratigraphy had been known. Recognition of the reefy nature of the Shikhans and of the equivalence of the limestones of the Ufa Plateau with the detrital strata of the Artinsk has led to radical changes in interpretation during the last few years. And these facies changes present many problems that need to be solved by extensive and detailed mapping. Furthermore, there is still a vast amount of work to do before the faunas are fully known. The Soviet geologists are the first to emphasize the need of more work before the Permian problems can be solved.

It appears likely, also, that deposition was more or less continuous in the Uralian geosyncline from early Carboniferous to Permian time, while repeated movements occurred in the Uralian geanticline, with the result that hiatuses along the flanks of the present Urals are somewhat local and no discordances can be observed throughout most of the Permian basin.

Criteria to be used.—Extensive discussion of the Carboniferous-Permian boundary has reflected two distinct philosophies of stratigraphic classification. One school regards the classification, even in its larger brackets, as essentially artificial. To adherents of this school any boundary is satisfactory if it is generally accepted. Prior definition or established usage fix the limits of the system and it is necessary to locate the boundaries in other regions solely by correlation with the type section.

[67] D. V. Nalivkin, "Scientific Results of the Permian Conference," *Problems of Soviet Geology*, Vol. 7, No. 7 (1937). See also a full translation with annotations by J. S. Williams in *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22 (1938), pp. 771–76.

[68] "Abstracts of Papers," *Seventeenth Inter. Geol. Congress* (1937), pp. 81–111.

A second school of stratigraphers believes that the larger stragigraphic units are natural, at least in large parts of the world, being separated by hiatuses due to widespread (though not necessarily universal) continental emergences. Devotees of this philosophy believe that the original systemic limits based on reconnaissance work may have been unwisely drawn and should be changed in the light of wider experience. To them the type section is important as a point of departure but is not the sole basis for determining the systemic limits. The writer tentatively accepts this philosophy.

If there be a natural boundary between the Carboniferous and the Permian, it should be indicated by (1) a widespread stratigraphic hiatus (not necessarily a discordance), or (2) an important faunal change, or (3) by both.

The greatest emergences of the continents may be due to broad epeirogenic movements and eustatic changes of sea-level in which local orogenic disturbances are only incidental. The areal extent of the hiatuses is therefore more significant than the amount of local discordance, and the areal extent can not be demonstrated in a single type area.

Stratigraphic evidence.—In the region of the type Permian, the most widespread hiatus between the base of the *Triticites zone* and the base of the Triassic appears to be about at the base of the Kungurian, where Murchison originally drew the lower limit of the Permian. During the Kungurian epoch the Uralian seaway was much restricted, but deposition apparently continued along the axis of the geosyncline. However, this restriction, accompanied by a marked change of facies, is more likely due to local climatic conditions rather than to broad diastrophic changes. Probably no modern student of the Permian would advocate a return to this high boundary because to do so would (1) reduce the Permian to a unit of rather minor importance, and (2) do violence to the biologic evidence in other regions. Below this no conspicuous and widespread break has been demonstrated.

Until recently it was believed that the change from the calcareous deposits of the "Uralian" to the detrital deposits of the "Artinsk" corresponded with important regional movements. This was undoubtedly one of the chief reasons why Tschernyschew assumed that the limestones of the Ufa Plateau belonged to the Carboniferous instead of the Permian. The overlap of the Artinsk facies on different horizons in the Sarga and Irghina beds in the Kisel region appears to have been one of the things that inclined Gorsky and Tolstikhina to draw the base of the Permian higher than most of their colleagues

desired. But if the Artinsk is only a facies ranging in age from Middle Carboniferous to Kungurian, no widespread stratigraphic boundary can be drawn at its base.

On the occasion of the Permian excursion, it was evident that those who wished to place the Sakmarian in the Carboniferous were strongly impressed by the unconformable overlap of the Artinskian on the flank of the Shikhan Tra-Tau. But, if it be granted that this structure is a great reef or bioherm of Sakmarian age, as explained on page 255, *it is not necessary to assume that the unconformable overlap of younger beds on its flanks has any great time significance.*

Probably most qualified students of the Russian section will now agree that deposition continued over large parts of the Permian basin from Middle Carboniferous well up into Permian with only minor interruptions. It is no longer possible to accept the Artinsk facies as a distinct horizon younger than the limestones of the Ufa Plateau, or to interpret the incursion of these detritals as evidence of a single and far reaching uplift in the Urals.[69] On the contrary, it is increasingly evident that movements began in the eastern Urals as early as Lower Carboniferous time and later spread farther west as the geosyncline deepened and developed. Unconformities and the sudden incursion of coarse detrital deposits may be expected at numerous horizons in the flank of the present Urals, but probably have only local significance. In short, there is probably no profound break in this vast basin on which Carboniferous and Permian can be separated. Likewise we should not expect a profound and sudden faunal change, notwithstanding the fact that the rapid evolution of the fusulines, ammonites, corals, land plants, and reptiles gave a distinctive character to the Permian as a whole. Our problem is, as Karpinsky realized in 1889, to find the horizon with the most distinct innovations of types that are important in the Permian; we must expect a conspicuous increment of Carboniferous holdovers in the early Permian.

From the structural and stratigraphic point of view one major feature stands out in our section across the Russian platform and the geosyncline, namely, the beginning of a rapid evolution of the geosyncline at the beginning of Sakmarian time. The Moscovian as well as the zone of *Triticites* reach their maximum development far out in the basin and, with the exception of a limited area in the eastern part of the Orenburg region, do not thicken or change facies to any notable degree in the geosyncline. On the contrary, the succeeding beds of the Sakmarian and Artinskian series reach an aggregate thickness of 3,500 feet or more in the western part of the geosyncline where they are in

[69] D. V. Nalivkin, *op. cit.*, p. 599.

the calcareous facies; they thicken still more to the east and change rapidly to a detrital facies in which sandstones and conglomerates play a major rôle; however, they thin very rapidly to the west and if present are very thin over the center and the western half of the Russian platform. The Kungurian is likewise largely restricted to the geosyncline, where its thickness reaches to 4,500 feet. Following its deposition, the geosynclinal area ceased its rapid subsidence, the Kazanian sea spread widely over the foreland, and a wide coastal plain of confluent deltas built westward from the Urals. These relations are believed to have obtained over a great region, including at least most of the southern and all the middle part of the Urals. The history of the northern Urals is less well known because of the overlapping Jurassic and Quaternary deposits.

The greatest physical change in this entire history appears to have been initiated at the beginning of Sakmarian time, when the Uralian geosyncline began to deepen rapidly and the eastern mobile axis of the Urals began to rise so as to supply detrital sediments in sufficient volume to dominate the eastern part of the geosyncline. This appears to the writer to mark the beginning of Permian time.

In America, there is a widespread and important break below the *Pseudoschwagerina zone.* It is most strikingly displayed in the Glass Mountains, where the Wolfcamp formation rests with profound unconformity across the closely folded Pennsylvanian formations. Along the edge of the Sierra Diablo and the Hueco excarpments, 200 miles and more northwest, the diastrophism was less marked but in both areas there is angular discordance between the Pennsylvanian beds (there called Magdalena) and the Hueco formation with *Pseudoschwagerina;* and although in places the *Triticites zone* is in part represented, the Hueco overlaps onto the *Fusulina zone* and, indeed, onto the pre-Cambrian. Still farther west, in southern Nevada, the contact lies in a thick limestone series, but a preliminary study of the fusulines indicates that the upper part of the *Triticites zone* is probably absent, and in northern California the *Pseudoschwagerina zone* (McCloud limestone) rests on Lower Carboniferous. But in central Texas and the northern Mid-Continent region there are no marked discordances in the entire sequence except locally about the flanks of the Arbuckle Mountains in Oklahoma, where several unconformities occur. However, an hiatus due to erosion, and marked by channels filled with sand, has been described by Moore at the base of the Big Blue series in Kansas. It is perhaps less marked than similar hiatuses below the Virgil and the Missouri series.

In South China and Indo-China there is a very great hiatus below

the Chuanshan limestone which contains the *Pseudoschwagerina fauna*. It is regional in extent as indicated by Fromaget and by Huang both of whom show the beds with *Pseudoschwagerina* to spread far more widely than those of the Moscovian. Hanzawa has also informed the writer that in Japan, South Manchuria, and Korea this zone rests directly on beds of Moscovian age with *Fusulina*. In the Orient, therefore, as in the Permian basin of southwestern United States, the *Pseudoschwagerina zone* overlies a regional hiatus of great magnitude.

Faunal evidence.—The task of reviewing and analyzing all the faunal evidence on the Carboniferous-Permian boundary is entirely beyond the scope or the purpose of this paper.

The fusulines confirm the importance of the break in America and in the Orient below the *Pseudoschwagerina zone*. A marked faunal change occurs at this horizon with the sudden appearance of the genera *Schwagerina*, *Pseudoschwagerina*, and *Paraschwagerina*, which burst into dominance among the fusulines as *Triticites* rapidly declines. While by no means a profound enough biological change to establish the beginning of a new system, it lends some weight to the stratigraphic evidence, and at the same time provides a very practical key horizon on which the base of the Permian may be drawn.

The evidence derived from the ammonites has recently been summarized by Ruženčev[70] and confirmed by Miller, who also regards the Wolfcamp and Sakmarian ammonites as Permian.[71]

Acknowledgments.—In a summary of this sort the works of many others are necessarily drawn upon. The use of published information is indicated by footnote references, but to an unusual degree the writer is indebted to his colleagues, both in Soviet Russia and in America, for information given in conversation and correspondence. During the never-to-be-forgotten days of the Permian excursion of the last International Geological Congress, he enjoyed the privilege of discussing various features of the Permian stratigraphy in the field with such leading Sovient students as Nalivkin, Gorsky, Rauser-Chernoussova, Tolstikhina, Ruženčev, Likharev, and Doutkevitch. In addition, while serving as chairman of the Permian subcommittee of the National Research Council's committee on stratigraphy, he has enjoyed the advantages of repeated conferences and much correspondence with the leading students of the American Permian. Recent

[70] V. E. Ruženčev, "The Boundary between the Carboniferous and the Permian, *et cetera*," *Abstracts of Papers, Seventeenth Inter. Geol. Congress* (1937), p. 89.

[71] A. K. Miller, "Comparison of Permian Ammonoid Zones of Soviet Russia with Those of North America," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22 (1938), pp. 1014–19.
V. E. Ruženčev, "Ammonoids of the Sakmarian Stage and Their Stratigraphic Significance," *Problems of Paleontology*, Vol. IV (1938), pp. 203–85, Pls. I–VII.

coöperation with the committee of the American Association of Petroleum Geologists has extended the range of those to whom the writer is indebted. Space will hardly permit mention of all these, but it is a pleasure to acknowledge particular indebtedness to Philip B. King, Hugh D. Miser, R. K. DeFord, C. W. Tomlinson, R. C. Moore, James Steele Williams, Norman D. Newell, and Arthur K. Miller. None of these must be held responsible, however, for any of the interpretations given in this paper.

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CARBONIFEROUS-PERMIAN BOUNDARY[1]

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ABSTRACT

Consideration of the requisites of a systemic classification that is practically most useful in all parts of the world emphasizes the importance of substantial agreement among geologists in acceptance of designated major divisions and of the nomenclature applied to these divisions. Likewise, greatest possible uniformity of usage in definition of systemic boundaries is obviously desirable.

The Carboniferous and Permian systems, respectively understood to include post-Devonian pre-Permian and post-Carboniferous pre-Triassic rocks, are considered to be among major divisions that should be recognized generally. Agreement in precise definition of the Carboniferous-Permian boundary, both in the type areas and elsewhere, offers difficulties. The paper here offered undertakes to clarify principles that apply to solution of this boundary problem, considers divergent previous usage and present views, and states conclusions that, it is hoped, will contribute to ultimate general agreement.

The lower boundary of the Permian, as now placed in most sections of North America and western Europe, appears to be stratigraphically below the position of this boundary in the type Russian section. Revision of the Carboniferous-Permian boundary in Russia, as advocated by Ruženčev, Nalivkin, Dunbar, and others, removes evident inconsistencies that otherwise exist, and this change appears to make classification accord best with paleontologic and stratigraphic relationships in different parts of the world. Acceptance of the revision and of the definition of this boundary given in the report of the Permian committee of the American Association of Petroleum Geologists is recommended.

INTRODUCTION

The problem of definition of the boundary between Carboniferous and Permian rocks has been brought periodically to the attention of geologists, both in Europe and other continents. Some of the recent contributions on this subject are found in papers by Dunbar (1940), Grabau (1931), P. B. King (1934), Romer (1935), Ruženčev (1937), Schuchert (1928), and Wheeler (1934). It is obvious that diversity in placement of this boundary by workers in any one region, and discordance in definitions employed in different regions, are sources of confusion, to be avoided as far as possible.

A committee of the American Association of Petroleum Geologists, appointed to make recommendations on classification and nomenclature of Permian rocks in North America, has prepared a report in which it is proposed that the lower limit of this system in the western Texas section shall be drawn at the unconformity separating the Wolfcamp beds (zone of *Pseudoschwagerina*) from underlying rocks. This agrees with previous usage among geologists in the western Texas area and accords with recent general practice in the Mid-Continent region of the United States, but, as will be shown, conflicts with definition of the lower Permian boundary that has long been

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current in eastern Europe and that is now accepted by numbers of Russian geologists who have studied the type Permian section. Some stratigraphers think that it is not permissible to classify certain American rocks (such as the Wolfcamp, Wichita, and Big Blue strata) as belonging definitely to the Permian, when European rocks that are agreed to be equivalent to them in age are very generally assigned to the Carboniferous system. Acceptance of this view requires placement of the Carboniferous-Permian boundary in North America above the Wolfcamp and corresponding beds rather than below them, or, alternatively, imposes necessity for at least such non-committal designation as "Carboniferous or Permian" for the *Pseudoschwagerina* beds. To classify this zone as "Carboniferous?" or "Permian?" seems somewhat less satisfactory as an expression of indecision, because the question primarily concerns definition of the lower Permian boundary in the European type section rather than uncertainty in correlation of American and Russian strata. Finally, it is observed that a tendency now exists toward revision of the Carboniferous-Permian boundary in the Russian section, and consideration should be given to the bearing of this on acceptable treatment of American stratigraphic classification as applied to the late Paleozoic rocks.

An extensive exchange of views among members of the Permian committee and some twenty or more other geologists, partly in oral discussion but largely in the form of circulated letters, has indicated some diversity of understanding both of pertinent facts and stratigraphic principles bearing on definition of the lower limit of the Permian. The subject is one of general importance, and accordingly, it has seemed desirable to review these matters.

Among questions that bear on the Carboniferous-Permian boundary, and, from the standpoint of principles involved, call for careful attention of all workers in stratigraphy, the following may be noted. (1) What are the essential criteria for definition of geologic systems and for establishment of the dividing lines between them? (2) What reasons underlie the almost universal acceptance by geologists of the world of such systemic divisions as Devonian, Cretaceous, Cambrian, Triassic, Jurassic, and others? Why is similar completeness of agreement lacking in classification of Cenozoic rocks, and in adoption of Ordovician, Ozarkian, Pennsylvanian, Kamilaroi, and other divisions that have been designated as systems? (3) To what extent and by application of what criteria may boundaries of geologic systems be revised? Does priority of definition have controlling importance? What weight, if any, is properly assignable to usage or majority opinion? Do conditions in the type region furnish the sole essential

foundation for determining the lower and upper limits of the system, or are stratigraphic observations in other parts of the world applicable to redefinition of systemic boundaries in the type sections? (4) What procedure is to be followed in adjusting the position of boundaries between systems when their respective type sections are discovered to contain equivalent beds? (5) How may systemic boundaries be fixed in sections containing younger or older beds than are represented in the type areas of the systems? These and similar questions are naturally raised in the minds of geologists when they are confronted with the problem of assigning classificatory rank and stratigraphic limits to American rocks called Permian. Such questions are inevitable also, in deciding whether or not the Carboniferous system should be recognized in American classification, and if accepted, whether its upper limit should be defined as in Europe to exclude the Permian or, on the other hand, to include it.

In seeking satisfactory answers to questions of the sort just given, it is well to remind ourselves that stratigraphic principles have not been set up in codified form as a group of Laws or Rules. Except on the basis of a consensus of judgments, it is not possible to formulate definite rules for stratigraphic classification and nomenclature, and no one is under compulsion to follow one procedure rather than another. Collective experience and reasoning, however, have gradually developed a fairly solid ground on which to base concepts of what is sound or unsound and desirable or undesirable in efforts to advance stratigraphic science. Broadly speaking, substantial uniformity of criteria for classification and of usage in stratigraphic nomenclature may be expected to produce greatest common understanding. In no case, however, should this uniformity prevent consideration of innovations or revisions on their merits. As a matter of fact, though conservatism and inertia may retard and even prevent universal acceptance of change, there are many instances in which meritorious changes have been accepted everywhere. It is also true that innovations without merit have received at least temporary acceptance by some. The objective of reasonable stability in stratigraphic classification is not incompatible with progress in this field of research, but it is opposed to the confusion of unlimited variation.

PRINCIPLES BEARING ON DEFINITION OF SYSTEMIC BOUNDARIES

BOUNDARIES IN STANDARD SECTION

Development of the classification of the geologic column leading to differentiation of systems has been the product of work by many geologists, following unequally understood and unevenly applied criteria. Conflicting interpretations have led in some cases to bitter

controversies. In spite of inevitable defects, a fairly acceptable and, therefore, an approximately stable classification has been produced and is now generally applied to rocks of the world. The main principles that have guided classification of rocks in systems may be sought by examining the characters of various recognized and proposed systemic divisions, first confining attention to the type regions.

Concepts of the divisions termed systems appear to have been introduced first and developed most in the course of early work by English geologists. Earliest among major stratigraphic units of the British Isles to be differentiated was the "Carboniferous order" (Conybeare and Phillips, 1822), which was originally defined to include the great succession of apparently conformable sandstone, shale, limestone, and coal beds lying between two prominent angular unconformities that are observable in western and northern England (Fig. 1). The lower unconformity, in southern Scotland, separates subhorizontal, moderately tilted or folded Old Red sandstone from underlying highly folded and metamorphosed slaty rocks (Silurian and older). The Old Red sandstone is overlain conformably by limestone and shale, classed as Lower Carboniferous. In the Pennine region of northern England, which, more than any other district, is considered to be the type area of the Carboniferous system, the complexly deformed older Paleozoic rocks are directly overlain by limestone and shale that are definitely younger than the Old Red sandstone (Fig. 1B). The upper unconformity divides the gently folded Coal Measures from nearly flat-lying red sandstone, marl, and magnesian limestone (Permian), together with overlapping younger deposits, that offer sharp contrast in lithologic and paleontologic characters to the Carboniferous strata (Fig. 1A). The Old Red sandstone was included by Conybeare and Phillips in their original definition of Carboniferous, probably because the Old Red conformably (or only disconformably) underlies the Lower Carboniferous marine shales and limestones, both in Scotland, Wales, and southwestern England. Subsequently, the Old Red sandstone was split off as an independent systemic unit, evidently on the ground of its great dissimilarity in lithology and fossil content from the overlying, dominantly marine Carboniferous rocks. Some British geologists class the Old Red sandstone as part of the Devonian system, but in various reports of the Geological Survey of Great Britain, both old and recently published ones, these strata are designated as the Old Red Sandstone system. It is apparent that the basis for the original definition of the Carboniferous system was primarily structural,—the occurrence of the prominent unconformities, marking important interruptions in the stratigraphic record. The presence of unconformities within the Carboniferous and other sys-

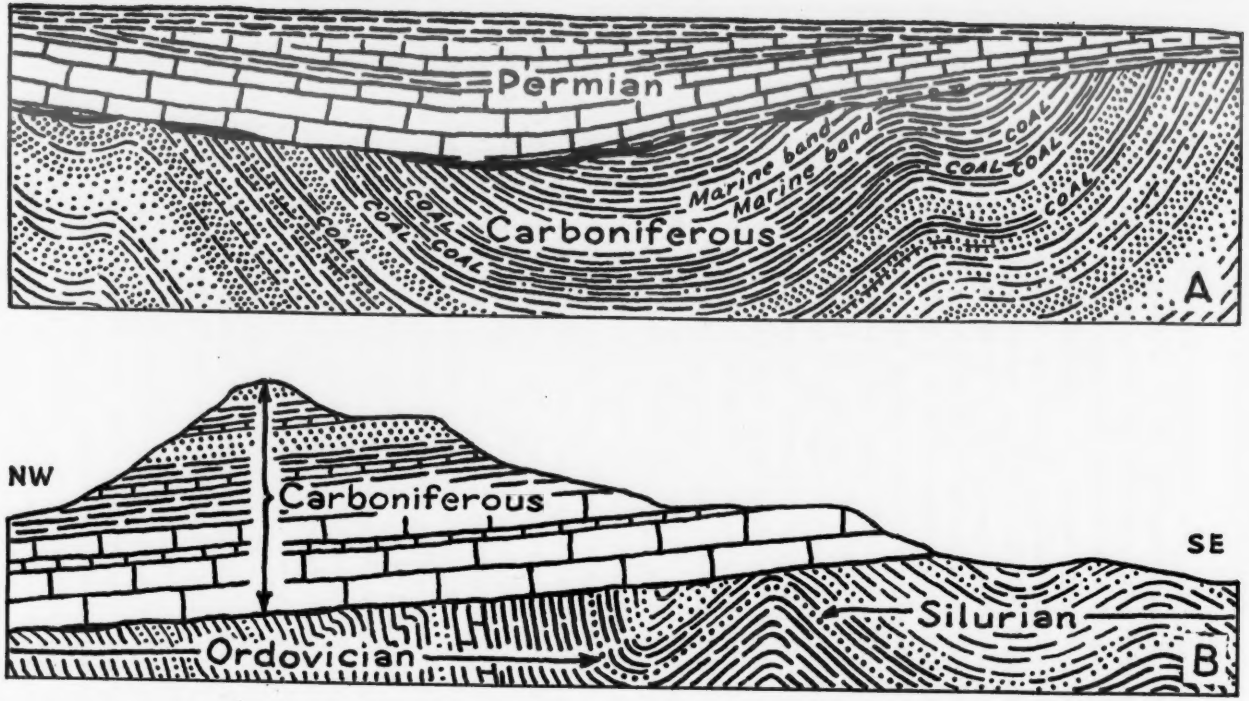

FIG. 1.—Sections showing nature of lower and upper boundaries of Carboniferous system in type region of northern England. *A*. Diagrammatic section of Carboniferous and Permian strata in Yorkshire and Nottinghamshire, showing unconformable boundary. *B*. Section through Ingleborough district in Pennine Uplands. (Redrawn from D. A. Wray, 1936.)

tems, as defined, is not to be overlooked, however (Fig. 2). The Carboniferous faunas (excluding those of the Old Red sandstone) possess general similarities, because they show progressive evolution of persistent life assemblages during a connected span of geologic time, although there are important dissimilarities due to facies. Lithology or thickness was not particularly important in defining the boundaries of the original Carboniferous system, but later on, lithology appears to have been given weight in restricting the lower limit of the system.

The Cambrian (Sedgwick, 1835) and Silurian (Murchison, 1835) systems were first defined on the basis of outcrops in west-central England and Wales. There was conflict of definition for many years, due to Sedgwick's inclusion of lower Silurian strata in his Cambrian and Murchison's incorporation of upper Cambrian in his Silurian. This was ultimately resolved by restriction of the upper boundary of the Cambrian and by introduction of the new division, called the Ordovician system (Lapworth, 1879). Differentiation of these three lower Paleozoic systems in their type areas is made on structural grounds—occurrence of angular unconformities—and paleontologic criteria. The revision of the boundary at the top of the Cambrian has been accepted almost universally, for there is a marked change in faunas at this line, which, in the type region, is marked by an important angular unconformity. Many European geologists continue to recognize the Silurian system as embracing the Ordovician rocks, which are classed as a series. In parts of the type area, the Silurian rocks lie disconformably or nonconformably on the Ordovician (Fig. 2B), but in other parts the succession is reported to be conformable. In considering the downward extension of the Silurian, it is evident that Murchison was impressed overwhelmingly by what he thought was the similar complexion of the marine faunas in all the included rocks. The upper limit of the Silurian system in parts of the type region, as south Wales, is defined plainly by the unconformity that separates folded rocks, below, from slightly deformed Old Red sandstone, above. Elsewhere in this same region and in west-central England, sandstone deposits (Downton) of Old Red type, lie conformably on marine Upper Silurian beds and are included in the Silurian system. Also, the lower Old Red sandstone, which is not included in the Silurian, rests conformably on the Downton sandstone, and an important unconformity separates upper and lower Old Red sandstone divisions. Paleontologic criteria appear to have chief weight in definition of the boundaries. These observations indicate that if the systemic boundaries noted are properly defined, important unconformities may or may not coincide with the boundaries, and they may or may not occur within the limits of systems.

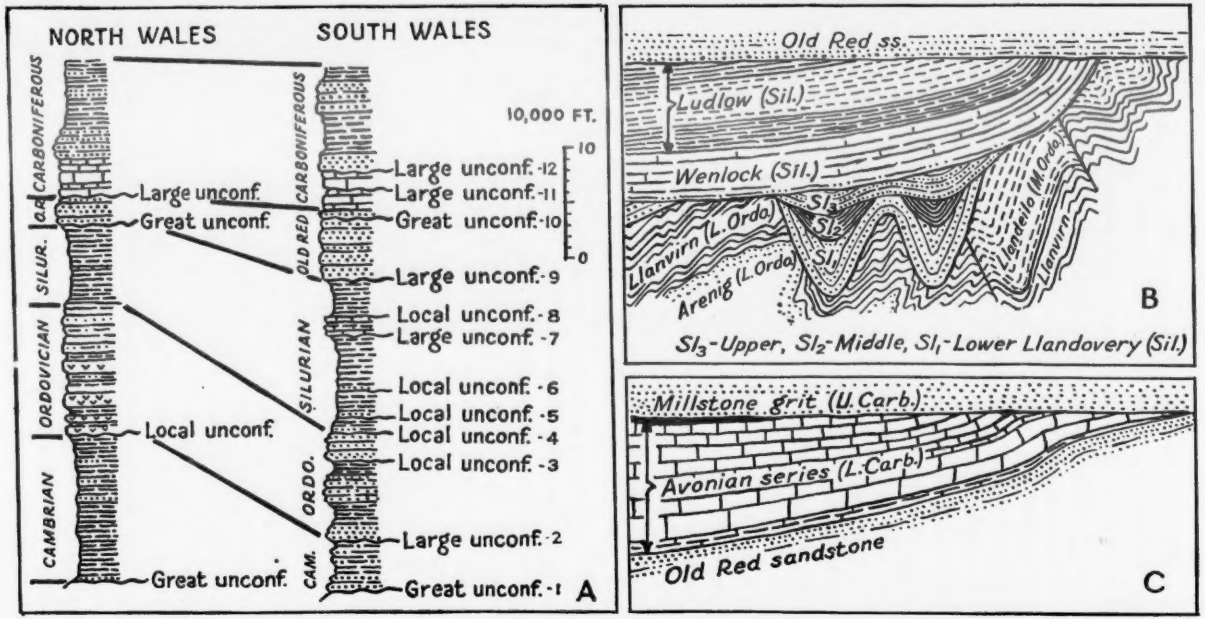

FIG. 2.—Unconformities in relation to boundaries between systems. *A*. Generalized columnar sections of Paleozoic rocks in Wales, type region of Cambrian, Ordovician, and Silurian systems, showing distribution and relative magnitude of unconformities (data from B. Smith and T. N. George, 1935, and J. Pringle and T. N. George, 1937). It should be noted that important breaks are recorded within divisions that are classified as systems and that contacts between some systems are conformable in this region. *B*. Diagrammatic section of older Paleozoic rocks in part of southern Wales, showing unconformities between systems and between some of their subdivisions (data from Pringle and George). This diagram illustrates unconformities numbered 4, 5, 6, 7, and 9 of Figure 2A. *C*. Section showing nature of boundaries at base and top of Lower Carboniferous series in southern Wales (after Pringle and George). Strata equivalent in age to Kinderhook lie conformably on Old Red sandstone. Boundary between Lower and Upper Carboniferous (No. 12 in Fig. 2A) does not correspond with that between Mississippian and Pennsylvanian in North America for the lower Millstone grit is Chester in age.

The Devonian system (Sedgwick and Murchison, 1839) was introduced to embrace marine deposits in southwestern England occupying the position of the Old Red sandstone. These rocks occur below the Carboniferous, as restricted, and commonly are separated from the Silurian by an unconformity. Where marine Devonian beds underlie marine Carboniferous strata, as in Devonshire and adjacent areas, the boundary is defined wholly and somewhat arbitrarily on paleontologic grounds,—at a horizon where a slight but detectable change in faunal content appears. The Devonian-Carboniferous boundary is similarly drawn solely on paleontologic characters in some near-by sections of continental Europe. This boundary has been revised downward (Schindewolf, 1928; Paeckelmann and Schindewolf, 1937) and this change is generally accepted.

The Permian system was differentiated from Carboniferous rocks, below, and Triassic rocks, above, on the basis of observations by Murchison (1841) in Russia. Dunbar (1940) has recently noted that Murchison's chief criterion for recognition of the Permian as a distinct system appears to have been biologic, although there is indication that correlations based on lithology were given much weight. Murchison erroneously identified the "grits of Artinsk" as equivalent to the Millstone grit (lower Upper Carboniferous) of England, thus placing his lower boundary of the Permian at the contact of divisions that are now designated as Kungurian and Artinskian. On the basis of extensive study of ammonoids from the Artinsk beds, Karpinsky (1889) concluded that the Carboniferous-Permian boundary should be placed below the Artinskian strata. This judgment was accepted and Karpinsky's revision of the lower Permian boundary became unquestioned. Subsequent proposals (Beede and Kniker, 1924; Ružencev, 1937; Dunbar, 1940) have been made to lower the boundary in the Russian section still farther, to a position at the base of the so-called Sakmarian beds, which contain the zone of *Pseudoschwagerina*. This pre-Sakmarian boundary corresponds to the base of the Wolfcamp series in western Texas. Grabau (1931, pp. 386, 405), Schuchert (1935, pp. 11, 19) and N. P. Guerassimov (see J. S. Williams, 1938, p. 773) have advocated placement of the lower boundary in the type section at the base of the "Uralian," at a horizon that corresponds approximately to the Missouri-Virgil boundary in the Pennsylvanian rocks of North America.

The Mesozoic systems have been defined in a manner essentially similar to those of the Paleozoic era, but in the areas that may be considered to present the type sections of each, systemic boundaries are defined largely in paleontologic terms, supplemented to some extent by disconformities. Generally speaking, there are no strongly marked

angular unconformities or other indications of pronounced stratigraphic breaks at the position of these boundaries in France and Germany. It is apparent that striking lithologic distinctions between these systems in the western European area had a part in their differentiation, but paleontologic criteria were more important. The Mesozoic rocks of the region under consideration have not been uniformly classified during the past century in three divisions,—Triassic, Jurassic, and Cretaceous,—for in some reports the Lias, Oölite, and other units have been treated as systems. Classification of the Cenozoic rocks is as yet too varied to warrant discussion here.

There are many divisions called systems that have not been mentioned. Ozarkian, Canadian, Taconic, Waverlyan, Tennessean, Mississippian, Bendian, Pennsylvanian, Comanchean, Karroo, Cambrovician, Siluronian, Donbassian, Fengninnian, Chichibu, and Kamilaroi are some of these. It is worthy of note that each is presumed to comprise a succession of beds having paleontologic and lithologic characters that set them distinctly apart from immediately underlying and overlying strata. Breaks in the faunal sequence at bottom and top of these systems are accompanied by more or less widespread physical breaks, marked by disconformities or angular unconformities. The boundaries are commonly very clearly defined. Most geologists will readily grant, however, that the Chichibu system, for example, no matter how well it may be differentiated in its type region, fails to satisfy requirements as a standard major division of the geologic succession in different parts of the world. This may be due partly to the lack of any intrinsic advantages in recognizing this unit in place of the partially equivalent Permian and Carboniferous, but it is essentially due to the fact that it lacks world-wide acceptance. It is not used by a substantial majority of geologists.

This brief review indicates that, as applied to the type sections of various recognized systems, definition of boundaries is based on the following criteria, named in the approximate order of their importance: (1) unconformities that indicate important interruptions in sedimentation; (2) paleontologic breaks; and (3) marked changes in lithology. Each division recognized as a valid system is represented in the type region by deposits one to several thousand feet in thickness which implies that an important segment of geologic time was required for making the sedimentary record. It is evident from the record of numerous changes which have been made and accepted that systemic boundaries may be revised. Substantial agreement in usage is more important as a factor in definition of boundaries than priority of definition.

BOUNDARIES IN SECTIONS OTHER THAN STANDARD

Once the content and limits of a geologic system have been defined satisfactorily in a type region, it may appear that the task of the stratigrapher in dealing with other areas is merely to recognize equivalences in age, to make correlations with the standard section, and to draw boundaries that conform with those established in the type section. If observations in other areas indicate that definitions of systemic boundaries in the type sections are poorly conceived, proposal to revise classification of rocks in the type areas may be made. In any case, there is need for a standard of stratigraphic reference. Difficulties in determining precise correlations are to be expected. A primary objective of classification of rocks in systems is establishment of large divisions of the geologic column that represent significant partitions of time in earth history and that are applicable as a common denominator for stratigraphic treatment of rocks in all lands of the globe. It is entirely possible that several independent sets of geologic systems might have been proposed, each applying to a single continent or subdivision of a continent, and this has been advocated, at least half-heartedly, on the ground that differences in local history of sedimentation, diastrophism, denudation, and life development, like unrelated dynastic or other periods in the history of different peoples, should find full expression in classification. Only brief consideration, however, is needed to show that the endless interrelations of the geologic record in different places knit these together, and one is only partly intelligible without reference to others. In any case, it is decidedly preferable to have a standard classification that is understood by all—even though features of it appear imperfect and locally unsuitable, rather than to invite the possible alternative arrangements. Moreover, regional stratigraphic variations can be reflected in classification involving units of less than systemic rank. An outstanding virtue of geologic systems that are recognized by all geologists is the manner in which they serve as a common language. In proportion to the lack of universal acceptance of a systemic division throughout the world, it lacks both scientific and practical usefulness.

The observations just made bear first upon the question of what systems, among many that have been proposed, merit adoption. It seems pertinent here only to say that the Carboniferous system, embracing beds between Devonian and Permian, and the Permian system, embracing beds between Carboniferous and Triassic, should be employed in the stratigraphic classification of North America, because these divisions have become so firmly fixed by a century of usage, not only in Europe but throughout the world, that general adoption of an

alternative systemic classification of the late Paleozoic rocks seems very improbable. If, however, future studies indicate such suitability to classification of late Paleozoic rocks in all parts of the world that some other systemic divisions (for example, Mississippian, Dinantian, Avonian, Pennsylvanian, Namurian, Westphalian, Stephanian) are deemed acceptable by a substantial majority of geologists, use of Carboniferous would naturally be restricted or abandoned.

Next, sound geologic practice demands that definition of the boundaries of the Carboniferous and Permian systems in Europe and North America should not disagree. If there are strong reasons for placement of boundaries in the European type sections at some position other than that which seems desirable on the basis of the boundary selected in American sections, and if substantial weight of judgment and of usage in Europe differs from opinions of American geologists, it is clear that adherence to our choice of boundaries in spite of differences might be construed to constitute misuse of Carboniferous and Permian. Few will argue that because these terms have been and are often thus misused, good stratigraphy can countenance this.

Does revision of the lower boundary of the Permian system in the type region affect placement of the upper boundary of the Carboniferous system? This seems an odd sort of question, but it is a proper one. The type regions of these systems are on opposite edges of Europe, approximately 2,000 miles apart. The exact horizon in the Russian Carboniferous section that corresponds in age to the topmost Carboniferous, beneath the pre-Permian unconformity, in England is not known, for Upper Carboniferous deposits in the two regions are almost entirely different in facies,—dominantly marine in the east and continental in the west. Certainly, the Carboniferous-Permian boundary in Russia could not be lowered indefinitely,—into the Moscovian, for example,—without coming into conflict with definition of the Carboniferous as based on the succession in the British Isles. It does not appear, however, that to draw this boundary at the base of the Sakmarian beds in Russia would occasion any subtraction of Upper Carboniferous strata in England, for the Sakmarian is thought to be altogether younger than any part of the type Carboniferous section. Most geologists do not need to be reminded that the stratigraphic span of a system or series, or of various smaller units may be less extensive in the type section, both upward and downward, than that of beds elsewhere properly regarded as belonging to the same division.

Attention must be directed to the problem of determining the position of boundary between systems in a section that contains beds

younger than any of those represented in the type area of the older of the two systems, or beds older than any in the type area belonging to the younger of the two systems, or both. In these cases a boundary is drawn on the basis of paleontologic relationships of the added beds, supplemented by physical evidences, such as occurrence of a disconformity or marked change in lithologic characters.

It is theoretically proper, and, given sufficiently strong evidence, it is practically possible to secure acceptance of a systemic boundary in a new position, that is, one that calls for revision of definitions of systems in the type regions. Such a case may be the lower Permian boundary. Arguments based on paleontologic characters and stratigraphic differentiation of the *Pseudoschwagerina* zone in widely separated parts of the world have been advanced by Beede and Kniker (1924), Ružencev (1937), Dunbar (1940), and others, strongly supporting a pre-Sakmarian boundary.

CARBONIFEROUS-PERMIAN BOUNDARY IN STANDARD EUROPEAN SECTIONS

CARBONIFEROUS-PERMIAN BOUNDARY IN ENGLAND

The youngest known Carboniferous rocks in the British Isles are included in the Keele series, and possibly part or all of the conformably overlying Enville series, which attains a thickness of 3,500 feet in Warwickshire (Edmunds and Oakley, 1936, p. 53). On the basis of fossil plants, Dix (1937) considers that the Keele beds belong to the Stephanian (upper Upper Carboniferous), but Crookall (1932), one of the leading British paleobotanists, thinks that no Carboniferous strata as young as Stephanian are present in the British Isles. Bertrand (1937) concludes that the highest beds in the southern Wales coal fields are lowermost Stephanian. According to Elias (1937, p. 204) and Darrah (1937, p. 118), this corresponds to a position in the American Pennsylvanian that is probably not higher than the lower part of the Virgil series (Douglas group) or the middle Conemaugh beds. The Enville beds are unfossiliferous redbeds containing coarse conglomerates and breccias, the constituents of which are identified as coming from Lower Carboniferous and Silurian limestones and pre-Cambrian volcanics. On the basis of lithologic characters the Enville has been referred to the Permian, but because the deposits are conformable on the Coal Measures, they are now classed as Upper Carboniferous or ?Permian (Edmunds and Oakley, 1936, p. 54). The conclusion that these continental beds, which have yielded a very few plants, belong to the Lower Permian Rotliegende series (Dix, 1937, p. 178) seems probably correct.

The lowermost Permian in northern England, found next above the post-Carboniferous unconformity, is correlated with the Saxonian (upper Rotliegende) deposits of continental Europe (Fig. 1A). The lower part of the Lower Permian (Autunian or lower Rotliegende) is absent.

Except possibly in the Warwickshire region of central England, the hiatus in the position of the Carboniferous-Permian boundary in the type area of the Carboniferous system is clearly very considerable. The division is sharply marked accordingly, but study of this section throws no light on the question as to whether the upper limit of the Carboniferous should be placed above or below the zone of *Pseudoschwagerina* in the more complete sections of eastern Russia and the Mid-Continent region of the United States.

CARBONIFEROUS-PERMIAN BOUNDARY IN RUSSIA

As noted previously, Murchison's original placement of the lower boundary of the Permian system was above the Artinsk grits, at the base of beds now classed as the Kungurian series. Revision of this boundary, due mainly to paleontologic studies of Karpinsky (1889), caused the Artinskian to be included in the Permian, and this has been accepted almost universally. Tschernyschew's (1902) elaborate monograph on Upper Carboniferous brachiopods of Russia designates the uppermost part of the Carboniferous as the *Schwagerina* horizon, C_3^3, and the next higher division, the Artinskian, is classed as Permo-Carboniferous. As explained by Dunbar (1940), "*Schwagerina*" of older writers corresponds to *Pseudoschwagerina* of present paleontologic nomenclature, and *Pseudofusulina* of Dunbar and Skinner is now called *Schwagerina*. This is confusing, but it happens that true *Schwagerina* (present usage) commonly occurs in association with *Pseudoschwagerina* and a related genus, *Paraschwagerina*. Tschernyschew's "*Schwagerina*" zone is included in the Sakmarian series of Ružencev (1935) and corresponds to the Wolfcamp series of Texas, the Big Blue series in Kansas, and equivalent strata. Without observed exception, until recent years, definition of the Carboniferous-Permian boundary in the Russian section has been placed by authors between the "*Schwagerina*" (*Pseudoschwagerina*) beds, below, and the Artinskian strata, above. The following citations from stratigraphic texts are representative of a list that might readily be made much longer.

LAPPARENT, A. DE, *Traité de Géologie*, pp. 1–2014. Masson, Paris (1906).
Table of Carboniferous divisions shows for Russia and Urals region "Calcaire *à Schwagerina* de l'Oural" as topmost part of "Ouralien ou Stephanien" (p. 974). Table of Permian divisions shows in Russia the "Artinskien (Grés d'Artinsk)" as lowermost part (p. 1026).

HAUG, E. *Traité de Géologie*, pp. 1–2021. Colin, Paris. (1908–1911).
Discusses rocks of the Anthracolithic period in the Urals region of Russia, the uppermost part of the Uralian consisting of the *Schwagerina princeps* limestone (p. 761). The Permian of the Urals region begins with the Artinskian, which consists of two parts, the Artinsk grits, below, and the Kungur dolomites, above (p. 793).

KAYSER, E., *Lehrbuch der Geologischen Formationskunde*, Bd. I, pp. 1–531. Enke, Stuttgart (1923).
"The closing stage of the Russian Upper Carboniferous comprises the *Schwagerina* beds, especially developed in the Volga district (Samara etc.) and northern Russia. These are characterized by the occurrence of *Schwagerina*, including *S. princeps*. . . . Next above the *Schwagerina* beds the Artinsk stage of the Permian occurs" (p. 309). Table shows *Schwagerina* beds as topmost zone of Upper Carboniferous in central Russia, Urals, and Timan region (p. 311).

HARRASSOWITZ, H., "Die Karbonformation," in W. SALOMON, *Grundzüge der Geologie*, Bd. 2, pp. 228–72, Schweizerbart, Stuttgart (1926).
Table of the Russian Carboniferous shows topmost division to be the "*Schwagerina* beds, very fossiliferous, with *S. princeps, Agathiceras, Pronorites*"; forms part of the "Ural Stufe (Ottweiler)" (p. 257).

COMITÉ GÉOLOGIQUE DE L'U.R.S.S. (P. BOUTOV, B. YAVORSKY, T. DOBROLIOUBOVA, J. GORSKY, L. LIBROVITSCH, A. TCHERNOV, M. YANISCHEVSKY, D. NALIVKIN, V. ROBINSON), "Materiaux pour servir à l'étude de la stratigraphie du Carbonifère dans les differentes régions de l'U.R.S.S.," *Congrès de Stratigraphie Carbonifère, Heerlen, 1927, Comptes Rendus* (1928), pp. 141–204.
"The Upper Carboniferous (C_3) is divided in two stages, the Gjel stage, below, and the *Schwagerina* stage, above" (p. 147). This is followed by the Artinskian (P_1) beds (p. 154).

SCHMIDT, H., *Tierische Leitfossilien des Karbons*, pp. 1–107. Borntraeger, Berlin (1929).
Upper part of Upper Carboniferous of Russia consists of the *Schwagerina* beds, correlated with the upper Stephanian (p. 2). Describes *Schwagerina princeps* as guide fossil of Upper Carboniferous (p. 5).

BUBNOFF, SERGE VON, *Geologie von Europa*, 4 vols., pp. 1–1607. Borntraeger, Berlin (1926–1936).
Stratigraphic table of the Russian Carboniferous shows top division (C_3) consisting of limestone with *Schwagerina* and other fossils (Bd. I, p. 78). Classes Artinskian as lowermost Permian, but cites three-fold division of Artinsk by Frederiks which places Sakmara beds (Sakmarian), present only in southern Urals, as lowest part of Artinskian (p. 82).

GIGNOUX, M., *Géologie Stratigraphique*, pp. 1–709. Masson, Paris (1936).
Table for marine Russian Carboniferous and Permian shows boundary above Uralian and below Artinskian (p. 175). "*Fusulina* appeared in the Moscovian, *Schwagerina* in the Uralian, and *Doliolina, Neoschwagerina* and *Sumatrina* . . . in the Permian" (p. 183). "Upper Carboniferous (C_3) of Russia comprises a lower part (Gjel stage) . . . and an upper part, the Uralian proper, which is everywhere marked by the appearance of schwagerines. These beds are followed by the Permocarboniferous (PC) of Russians, which is here referred to the Lower Permian" (p. 235). Table shows *Schwagerina* stage (C_3^3) comprising uppermost part of Upper Carboniferous (p. 239). Artinskian classed as lowermost division of the Permian (p. 251).

FREDERIKS, G., "The Permian of the Ural Region," *Intern. Geol. Congress, Rept. 16th Sess., U. S. A.*, Vol. 1 (1936), pp. 657–62.
Table classes Artinsk as Middle Permian (follows p. 662). Lower Permian (P_1) considered to be absent throughout the Ural region but present in the Donetz basin. The *Schwagerina* zone and even higher limestones are considered to be Upper Carboniferous.

NALIVKIN, D., "Major Divisions of the Paleozoic of the Union of Soviet Socialist Republics," *ibid.*, pp. 573–83.
Upper Carboniferous contains "*Schwagerina* fauna at different horizons." The succeeding Artinsk constitutes the lowermost division of the Permian system. (Table follows p. 583.)

The unanimity of treatment in the references just given seems to allow little room for question as to what has been the generally under-

stood usage among European geologists concerning definition of the Carboniferous-Permian boundary in the eastern Russian area. Undoubtedly, the basis for this definition has been the opinion of Russian authorities, especially Karpinsky and Tschernyschew. Dunbar[3] emphasizes the inaccuracy and unreliability of the stratigraphic concepts underlying the statements as to the post-"*Schwagerina*" pre-Artinsk position of the Lower Permian boundary. He writes:

> It is important to remember and to make clear that the traditional boundary between the *Schwagerina* zone and the Artinsk was not a time boundary but a boundary between two facies, and that the limestone facies of the Artinsk was being classified as Carboniferous while the detrital facies was called Permian. This is important because it shows how unsatisfactory the criteria were upon which that boundary was drawn. Likewise, while there may be some merit to citing the several big works that accept this boundary, it is also important to realize that, between 1902 and about 1920, no critical work whatever was done on this problem and all of the general treatises cited by you rest on the same mistakes and are merely a repetition of a fallacy. In such a case, repetition does not strengthen the contention.

These are pertinent comments, but it remains true that essentially uniform usage, even if based on inadequate or erroneous understanding, has tended to fix definition of the Carboniferous-Permian boundary.

Studies of the Carboniferous and Permian rocks of Russia in recent years have added considerably to knowledge of the stratigraphic relations of various parts of the succession and of the fossils of different horizons. It has been learned that the brachiopod faunas described by Tschernyschew were partly misinterpreted as to field occurrences and misunderstood as to their actual stratigraphic span. New information concerning zones of ammonoids, bryozoans, and fusulinids has been obtained. The Artinsk deposits have been found to represent a facies, rather than a distinct zone. Evidence has been gathered to show that some of the "Artinsk" clastics in the Uralian geosyncline contain *Pseudoschwagerina* and that these deposits are time equivalents of *Pseudoschwagerina*-bearing limestone beds of the Russian platform area; also, that some beds of Artinsk facies in the southern Urals are apparently as old as Lower Carboniferous (see Elias, 1937a, p. 282).

Some Russian geologists (Nalivkin, Ružencev, Toumansky, and possibly others) who have studied the Carboniferous and Permian section carefully, and a number of Americans (Condra, Dunbar, Miller, and Newell) who examined critical exposures in the type Permian area, are of the opinion that the lower boundary of the Permian system should be set at the base of the Sakmarian series, below the zone

[3] Personal communication, September 14, 1939.

of *Pseudoschwagerina*. This has been reported in some detail by Dunbar (1940), who calls attention to the fact that the suggested revision of the lower limit of the Permian in the Russian section accords with recommendations made in 1924 from studies of the literature by Beede and Kniker. Arguments that the pre-Sakmarian boundary has much greater significance, both paleontologically and in physical stratigraphic relationships than one just above the *Pseudoschwagerina* zone, seem cogent, especially in view of present knowledge concerning the true nature of the rocks called Artinskian. Dunbar concludes very plausibly that the supposed important unconformity seen in places above *Pseudoschwagerina*-bearing limestone is merely a reef-flank structure that does not signify much difference in age between rocks of the reef and overlapping beds. As matters stand, however, there is by no means any substantial agreement concerning acceptance of the boundary below the Sakmarian beds as the lower limit of the Permian system. Recent publications indicate that among Russian geologists the following place the Carboniferous-Permian boundary above the zone of *Pseudoschwagerina:* Dutkevitch, Gorsky, Ivanov, Khabokou, Licharev, Nikiforova, Rauser-Chernoussova, Tikchvinskaya, and Tolstikhina. As already noted, Nalivkin (who has apparently changed his opinion since his 1936 paper), Ružencev, and Toumansky have advocated placement of this boundary at the base of the *Pseudoschwagerina* zone (Sakmarian), and one geologist, Guerassimov, would apparently place it at the top of the Moscovian (approximately equivalent to the Des Moines-Missouri boundary). The opinions of several other writers are not clear. Williams (1938) has published a translation of Nalivkin's report of a conference at Leningrad in February, 1937, attended by about 75 geologists, "all specialists on the Permian system." A committee of seven was appointed to prepare a scheme of classification for the Lower Permian, and of this number, five would place the Carboniferous-Permian boundary above the zone of *Pseudoschwagerina*, one would place it below this zone, and the opinion of the remaining one is not given. Nalivkin states that "the Leningrad group," probably meaning geologists on the staff of the Central Geological Institute (corresponding approximately to the U. S. Geological Survey in this country), "favors a boundary above the *Pseudoschwagerina* zone" (Williams, 1938, p. 773). Farther on it is noted that "if the point of view proposed by the Leningrad group is accepted, then the existing geologic maps would need only a slight revision. On the other hand, if the opinion of Ružencev (who advocates a pre-Sakmarian boundary) is accepted, then the geologic maps should be revised drastically and the area occupied by the Upper

Carboniferous will be considerably decreased." This seems plainly to mean that opinion and usage in the U.S.S.R. did not agree substantially in favoring recognition of the base of the *Pseudoschwagerina* zone as the lower boundary of the Permian. There is division of judgment, a majority adhering to old views, as probably to be expected.

It is pertinent to add comments concerning the significance of errors that have been discovered in Tschernyschew's work. Dunbar (1940) has noted that in the Ufa Plateau Tschernyschew mistakenly considered limestones belonging far above the *Pseudoschwagerina* zone as equivalent to this zone, and in some cases as corresponding to still lower zones. He assumed without argument that all of the fossils collected from these rocks were Carboniferous. It is not surprising that Tschernyschew found close similarities between many of his fossils and those known from the Artinsk, the Sosio beds of Sicily, the Trogkofel limestone of the Alps, and the Productus limestone of India,—beds generally accepted as Permian but regarded by him as properly assignable to the Carboniferous. The discovery that Tschernyschew was actually dealing with a mixed assemblage of Upper Carboniferous and undoubted Permian fossils furnishes in itself no more argument for the conclusion that the *Pseudoschwagerina* zone belongs in the Permian than it does for similar assignment of still lower zones (*Cora* beds, *Omphalotrochus* beds) described by Tschernyschew, although hardly anyones entertains doubt as to the Carboniferous age of these latter. Schuchert (1928) and Grabau (1931), being impressed by the Permian aspect of Tschernyschew's brachiopod faunas, erroneously transferred to the Permian all of the zones from which these fossils came. Beede and Dunbar are quite right in emphasizing the point that the source of the widely accepted zonation and faunal characterization of beds assigned to the Russian Upper Carboniferous (Tschernyschew's work) is not to be taken at face value, but because many fossils from beds younger than the *Pseudoschwagerina* zone are confused with those actually belonging to this zone and to lower horizons, it is very difficult to reach any reliable conclusions on the basis of brachiopods reported by Tschernyschew as to location of the Carboniferous-Permian boundary.

CARBONIFEROUS-PERMIAN BOUNDARY IN NORTH AMERICA

PREVIOUS USAGE IN PLACEMENT OF BOUNDARY

Kansas, Oklahoma, and Nebraska.—Discovery of the existence of Permian rocks in North America was first announced in 1858 (Swallow). This was on the basis of fossils collected in the Kansas River valley, not far from the site of the present town of Junction City,

Kansas; the horizon represented was probably the Winfield limestone, but it may have been a little higher or lower. Determination of the Permian aspect of the fossils appears to have been made originally by Meek (Merrill, 1906, p. 485). The claim that Marcou recognized Permian beds in the central United States as early as 1853 is to be discounted, for there was no publication of this until much later, and Marcou (1864, 1868) erroneously classed undoubted Upper Carboniferous beds (Wabaunsee) as Upper Permian (Zechstein), as did Geinitz (1866).

A reconnaissance of the Kansas River section by Meek and Hayden (1859) in 1858 furnished data for a measured section of the Upper Carboniferous and Permian rocks that are well exposed in many places along the bluffs. Numerous fossil collections were obtained, and study of these by Meek led to the conclusion that the beds between the base of the Neva and top of the Fort Riley limestone (using modern names for the readily identifiable units of their section) contain a mingled assemblage of typical Carboniferous and early Permian marine shells. This zone was accordingly designated as Permo-Carboniferous. The true Permian was regarded by Meek and Hayden as beginning at about the top of the Fort Riley limestone (Fig. 3). The entire section was considered to be uninterrupted by a stratigraphic hiatus. A Kansas River section prepared by Swallow and Hawn (1859) places the base of the Permian rocks a few feet below the Neva limestone, and another section (Swallow, 1866) places it at the bottom of the "Dry Bone limestone" (Neva). Swallow did not recognize a division called Permo-Carboniferous, for he thought that the advent of Permian types of invertebrates should be interpreted to mark the beginning of Permian time in this region.

Practically no work on the Carboniferous and Permian rocks of Kansas was done in the period 1870 to 1890. After the International Geological Congress meeting in Washington, in 1891, Tschernyschew, whose work on the stratigraphic zonation and paleontology of the uppermost Carboniferous in eastern Russia established him as the leading authority on these rocks, studied the Kansas River section. He concluded that the beds now classified as Council Grove, and possibly the lower part of the Chase group, corresponded to the "*Schwagerinen* Horizont" which he defined as the highest division of the Upper Carboniferous in the Urals region (Tschernyschew, 1902, pp. 703, 706; also Prosser, 1905, p. 154). The upper Chase and Marion (Sumner) beds were considered to be of Artinskian age. Hay (1893) measured a section along the line studied by Meek, Hayden, and Swallow, and drew boundaries between the Carboniferous and

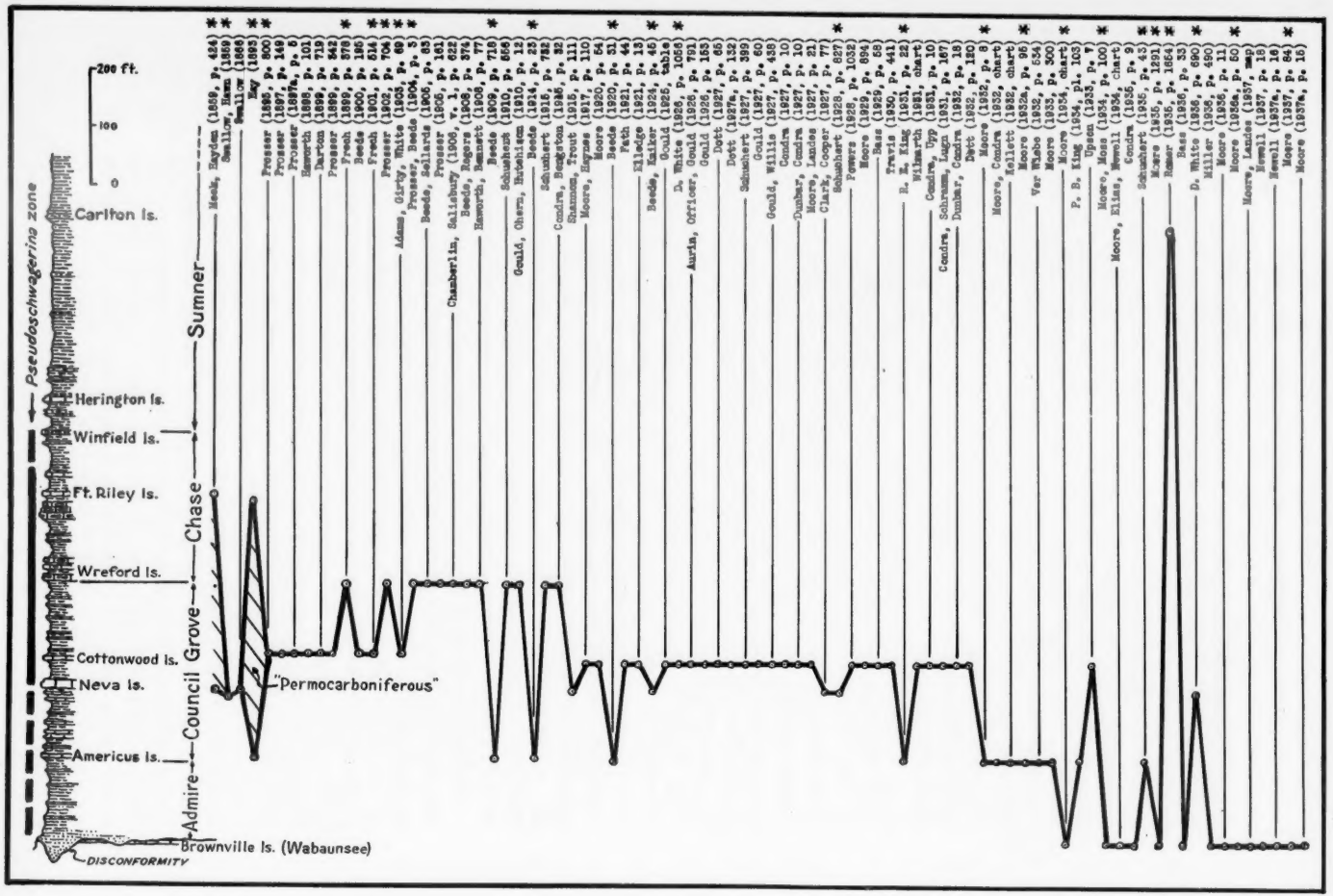

FIG. 3.—Diagram showing placement of Carboniferous-Permian boundary in northern Mid-Continent region. Only a representative indication, not an exhaustive survey of published usage is given. References listed in bibliography at end of paper. Citations marked by asterisk (*) are important because special consideration was given to problem of stratigraphic classification.

Permo-Carboniferous at about the horizon of the Americus limestone, and between Permo-Carboniferous and Permian at the base of the Fort Riley limestone. In 1895, Prosser published a classification of the rocks in this part of the Kansas column, concluding that the lower boundary of the Permian should be drawn at the base of the Neosho formation (base of Morrill limestone), 5–10 feet above the Cottonwood limestone. This boundary was accepted by Haworth (1895) and used in publications of the Kansas Geological Survey; it was also adopted by Beede (1900), Darton (1899), and others (Fig. 3).

It is evident from Prosser's discussion of the invertebrate faunas from various zones, as identified by him, that no clearly defined basis was found among these fossils for designation of a major stratigraphic boundary. He was apparently led to select the top of the "Cottonwood shales" (Florena) as the upper limit of the Carboniferous because this marked the horizon at which typical Coal Measures shells, like *Spirifer cameratus*, disappeared or became rare, and because forms believed to characterize Permian beds, like *Pseudomonotis*, *Bakewellia* and others, were common in higher zones. When the European paleontologist, Frech (1899), who was well acquainted with the late Paleozoic faunal succession in the Old World, announced the opinion that the Carboniferous-Permian boundary in the Kansas section should be placed a little higher than indicated by Prosser, the latter (1902) readily accepted the change recommended, which placed the lower limit of the beds called Permian at the base of the Wreford limestone. The Wreford boundary was employed in publications of the U. S. Geological Survey, the Kansas Geological Survey and in various scientific journals, though Frech (1901) had already returned to Prosser's original boundary.

About 1915 the official classification of the U. S. Geological Survey and of the state surveys in Kansas, Nebraska, and Oklahoma came to define the lower boundary of the Permian as belonging at the base of the Cottonwood limestone. First publication using this definition appears to have been by Darton (1915, sheet facing p. 22) but no discussion of placement of the boundary is offered. Through the kindness of H. D. Miser, chairman of the Committee on Geologic Names of the Federal Survey, and Miss Alice S. Allen, secretary of the committee, records have been searched without bringing to light any pertinent information under date of 1915 or immediately preceding years, except a notation under Garrison shale (the formation next above the Cottonwood limestone): "Permian, D. W. Mar., 1915." This indicates an opinion of David White. The minutes of a meeting of the Geologic Names committee on July 26, 1916, contain

given to problem of stratigraphic classification.

the following account of deliberations concerning the lower Permian boundary, attention being focused especially on the Foraker Quadrangle in northern Oklahoma.

> For some time the Survey has been following Mr. White's conservative recommendation and placing the Permian-Pennsylvanian boundary at the base of the Cottonwood limestone . . . . Dr. Girty states there is strong evidence for placing the dividing line at the Foraker limestone, while Mr. Heald states that if the Foraker quadrangle alone were to be considered, the base of the Eskridge shale would appear to be the proper place to draw the line. Mr. White . . . joined the committee and stated that he had conclusive paleobotanical evidence that everything down to the base of the Cottonwood limestone is Permian, also that he has some evidence, which would be regarded as conclusive by most European geologists, for placing the boundary line considerably lower, but in view of the conflicting opinions he has been very cautious about recommending that the line be placed lower. He expressed the opinion that when the floras of the Eskridge are dug out and studied they will prove to be Permian, and he also said that the Elmdale material would be considered by most European paleobotanists as Permian, but he did not think the evidence is sufficiently conclusive to warrant assigning that formation to the Permian. He suggested that for the present the boundary be left where it is, but that the subject be freely discussed in Survey reports, and that on map legends the boundary between the two series be dotted, to indicate the uncertainty which exists.

The boundary at the base of the Cottonwood is practically equivalent to Prosser's designation of the lower Permian boundary in 1895, which was just above the Cottonwood. Although admittedly arbitrary, the line at the horizon of the Cottonwood limestone has been used far more commonly than any other to mark the base of the Permian in the northern midcontinent region (Fig. 3).

In 1924, Beede and Kniker (pp. 30–32) called attention to the occurrence of species of "*Schwagerina*" (now termed *Pseudoschwagerina* and *Paraschwagerina*) in the Wolfcamp formation of trans-Pecos Texas and in the Neva limestone of Kansas, and after a survey of the distribution of these fusulines in late Paleozoic basins of Europe and Asia, concluded that the zone of "*Schwagerina*" is of such stratigraphic significance that it should be recognized as an important marker wherever found. Instead of being classed as uppermost Carboniferous, as in Russia, they advocated definition of this zone as the initial subdivision of the Permian rocks. D. White (1926, p. 1057) confirmed the lowering of the Permian base to include the Neva limestone, some 50 feet below the Cottonwood, because of the Permian aspect of plants at the Neva horizon. Schuchert (1928, p. 827) and others also accepted the boundary at the bottom of the Neva.

The beds below the Cottonwood and Neva for a distance of at least 250 feet are lithologically and faunally so very similar to these limestones and the strata associated with them, they are so clearly a conformable succession, and they differ from undoubted Pennsylvanian beds in such degree that in 1932 (Moore, p. 89) the writer was led to conclude that if the Cottonwood and Neva are Permian, the lower limit of this system in the northern Mid-Continent region should be placed at least as far down as the base of the Americus limestone, about 150 feet below the Neva (Fig. 3). The Americus contains *Schwagerina* (modern usage, equivalent to former *Pseudofusulina*) and advanced types of large *Triticites*, both of which are common in the zone of *Pseudoschwagerina*. This is the lowest observed horizon in which *Schwagerina* occurs. The base of beds called Permo-Carboniferous by Hay (1893) was placed at the Americus, and the base of the Permian was drawn here by Beede (1909, 1914, 1918), although not consistently.

Field studies of strata that had been classed as upper Wabaunsee (Pennsylvanian) led to the discovery in 1934 (Moore and Moss, 1934) of what appears to be an important, though obscure, disconformity that is marked mainly by large channel sand fillings. The horzon of this break lies approximately 100 feet below the Americus limestone and it is traceable from Nebraska into Oklahoma, possibly even to the Arbuckle Mountains. The disconformity marks the lower boundary of the Admire group, as now defined, and is also the boundary now recognized by the Kansas and Nebraska surveys as the lower limit of the Permian (Fig. 3).

It is necessary, finally, to take note of a placement of the lower Permian boundary in the northern Mid-Continent that differs widely from others, excepting what appears to have been the real opinion of Girty (1908, pp. 38–50). This is proposed by Romer (1935, p. 1629) in an important contribution devoted primarily to discussion of the later Paleozoic vertebrates, but dealing with the problem of defining the Carboniferous-Permian boundary and considering all types of evidence. Romer concludes that the proper position for this boundary in the Kansas section is above the Carlton limestone member of the Wellington shale in the Sumner group. This is hundreds of feet higher than any other suggested horizon for the base of the Permian and it is approximately 1,000 feet above the disconformity that has been mentioned at the base of the Admire group. The essential basis for Romer's proposal is the paleontologic evidence, which points strongly to correlation of beds above this line with Artinskian strata of Europe and of beds below the line with pre-Artinskian strata; the

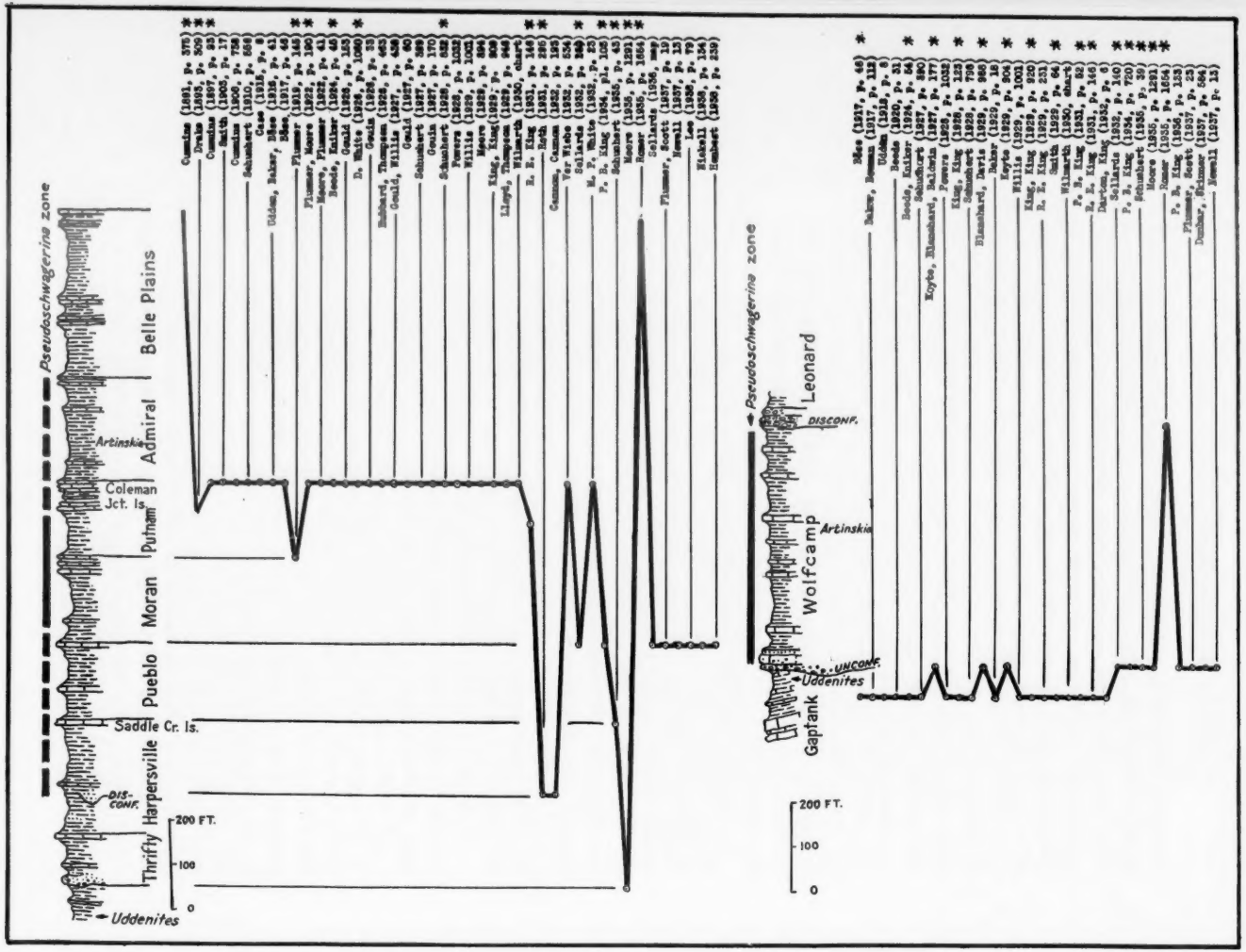

FIG. 4.—Diagrams showing placement of Carboniferous-Permian boundary in north-central Texas and western Texas regions. Only a representative indication, not an exhaustive survey of published usage is given. References listed in bibliography at end of paper. Citations marked by asterisk (*) are important because special consideration was given to problem of stratigraphic classification.

boundary in North America, Romer states, should be drawn to conform with definition of its position in Russia, which is well known to be the base of the Artinskian. Romer's treatment of the pertinent evidences is adequate and his conclusions appear entirely logical. Girty regarded the Big Blue invertebrate faunas as only slightly modified Pennsylvanian assemblages and questioned their assignment to the Permian, although he accepted placement (on the basis of fossil plants) of the lower boundary of the Permian at the base of the Wreford (Adams, Girty and White, 1904), (Fig. 4).

The diagrammatic representation of the changing position of the boundary at the base of the Permian in the northern Mid-Continent area, given in Figure 3, shows clearly the trend of usage, which, throughout most of the past half-century, has been to adopt an arbitrary line of division approximately at the horizon of the Cottonwood limestone. During late years there has been a definite tendency to lower this boundary, but this is interrupted by the proposal of Romer to transfer practically all of the Big Blue series into the Pennsylvanian.

North-central Texas.—Study of Texas sections of Pennsylvanian and Permian rocks is very important as regards definition of the lower Permian boundary, for the stratigraphic record is relatively complete and diagnostic fossils, both marine and continental, permit excellent paleontologic zonation. Recognition of Permian fossils in Texas was announced as early as 1858 (Shumard), and since that time knowledge has been advanced at approximately the same rate as in Kansas. Many interesting ammonoids, fusulinids, reptiles, and other fossils have been described.

Although several papers on fossil vertebrates classed as Permian were described from north Texas by Cope, beginning in 1878, the first detailed stratigraphic study was published in 1890. Cummins (1890, p. 187) defined vertebrate-bearing redbeds near Wichita as the Wichita beds, classifying them as lowermost Permian, and the subjacent division he designated as Cisco, assigning it to the Coal Measures. Farther south, Dumble (1890, p. lxvii) found non-red limestone and shale beds that he termed the Coleman-Albany group; this occurred next above the Cisco and both divisions were considered to belong to the Coal Measures. Cummins (1891, p. 375) thought at first that the Albany beds wedged in beneath an unconformity supposed to exist at the base of the Wichita redbeds, but later he (Cummins, 1897) accepted the view of Marcou (1892, p. 369) that the Albany and Wichita are contemporaneous deposits of different facies. This led to definition of the lower boundary of the Permian at the same horizon in the northern and southern parts of the area,

FIG. 4.—Diagrams showing placement of Carboniferous-Permian boundary in north-central Texas and western Texas regions. Only a representative indication, not an exhaustive survey of published usage is given. References listed in bibliography at end of paper. Citations marked by asterisk (*) are important because special consideration was given to problem of stratigraphic classification.

and the top of the Coleman Junction limestone was defined to mark the upper limit of the Cisco beds. The term Albany was dropped. The base of the Permian has been drawn consistently at the Cisco-Wichita boundary in almost all publications (Fig. 4).

In 1931, Roth (p. 295) reported the discovery of typical Neva fusulinids (*Schwagerina*, but not *Pseudoschwagerina* or *Paraschwagerina*) in the upper part of the Harpersville formation of the Cisco group, and this evidence was interpreted to signify that the lower boundary of the Permian should be placed in the Harpersville.

Sellards (1932, p. 140) has recently made revision of the Pennsylvanian-Permian boundary in north-central Texas, with accompanying redefinitions of the Cisco and Wichita groups. The new placement of the boundary is at the base of the Moran formation, about 300–350 feet below the Coleman Junction limestone. Essential basis for the change is the finding of specimens of *Pseudoschwagerina* and true *Schwagerina* in the Moran formation, some 70 feet below the Sedgwick limestone. According to statements by C. O. Dunbar (letter dated September 14, 1939) and J. W. Skinner (letter dated October 3, 1939) the reported occurrence of *Paraschwagerina* in the Moran formation of north-central Texas (Sellards, 1932, p. 144; Plummer and Scott, 1937, p. 394) is erroneous. This definition of the lower Permian boundary indicates the present official usage of the Texas Bureau of Economic Geology, and it has appeared in publications of that organization issued since 1932.

Romer's (1935) study of the Pennsylvanian-Permian boundary, already noted, leads to the determination that this line belongs at the top of the Wichita group in north-central Texas, rather than at its base. It should be noted, however, that Romer considers the Wichita group to comprise the Moran, Putnam, Admiral, and Belle Plains formations, excluding the Clyde and Lueders formations, above the Belle Plains. The Permian boundary of Romer in northern Texas is 1,000 feet higher than that of Sellards, just as his boundary in Kansas is 1,000 feet above the disconformity indicated by the writer as the Pennsylvanian-Permian boundary. Attention has been called by friends on the staff of the U. S. Geological Survey to the long-held but obscurely expressed judgment of G. H. Girty as to placement of the Lower Permian boundary in north-central Texas. Girty (1911, p. 126) accepted the Permian age assignment for the Wichita group in Texas, but "strictly on the paleobotanic evidence." It appears from reading between the lines that Girty's appraisal of invertebrate evidence indicated that the Wichita beds should be classed as Pennsylvanian, and this opinion is reported to have been

given orally by him at numerous times. The accompanying diagram (Fig. 4), which shows the position of the base of the Permian according to numerous writers on north-central Texas, indicates stability of usage until 1931. A somewhat violent "seismic" vibration is witnessed in the record of recent usage.

Western Texas.—Study of the rocks and fossils of the splendid Permian succession of trans-Pecos Texas is confined almost wholly to the last 35 years. Girty (1908) laid groundwork in an extensive paleontologic treatise. The work of Böse (1917), especially his description of western Texas ammonoid faunas, established the lower limit of the rocks classed as Permian at the base of the Wolfcamp formation. As originally defined, the Wolfcamp comprised beds in the lower part containing *Uddenites schucherti* and other ammonoids, and in the upper part beds containing "*Schwagerina.*" The *Uddenites* fauna was interpreted by J. P. Smith (1929) as distinctly more advanced than normal Pennsylvanian ammonoid assemblages, and accordingly he considered the *Uddenites*-bearing beds as properly assignable to the Lower Permian; this view was shared by Schuchert (1927) and many others. In 1931, Scott and Plummer (p. 355) reported discovery of *Uddenites schucherti* and associated ammonoids corresponding to the lower Wolfcamp fauna in the basal part of the Cisco group of north Texas. The lower Cisco horizon appears surely placed in the upper Pennsylvanian (Virgil). The opinion of Keyte, Blanchard, and Baldwin (1927) that the *Uddenites* beds of trans-Pecos Texas are Pennsylvanian rather than Permian was substantiated. Accordingly, Sellards (1932, p. 148) restricted definition of the Wolfcamp to exclude the *Uddenites*-bearing beds and the lower boundary of the Permian is now raised to this new base of the formation. Throughout most of the west Texas region, the Wolfcamp, containing the *Pseudoschwagerina* fauna, is found resting unconformably on various Pennsylvanian and older rocks down to the pre-Cambrian, the *Uddenites* beds generally being absent.

The views of Girty on correlation and age assignments of the late Paleozoic rocks of western Texas are important, both because of his many years of intensive study of Carboniferous and Permian invertebrate faunas and because of the influence that he has exerted (and continues to exert) on the opinions of Survey colleagues. The extreme caution of almost every published statement by Girty, with careful avoidance of commitments even in expression of opinion, and his discursive style in writing have operated to a limitation of his impress that may be deemed unfortunate. As for the west Texas section, Girty (1908, pp. 38–50) appears to have held a fairly definite opinion

that the Hueco limestone (as restricted by King, 1934, p. 742) fauna is older than his Guadalupian faunas and seemingly he thought (*op. cit.*, p. 48) the Hueco to be more closely allied to those of Russian Carboniferous (Gschelian) beds than to "Permo-Carboniferous" (Artinsk) or Permian faunas. The writer is unable to confirm King's (1934, p. 748) statement of Girty's opinion by finding reference, but it is probably not wrong to think that Girty regarded the Hueco as Upper Carboniferous. This last statement must be interpreted in the light of Girty's usage of Permian in 1908 (pp. 47, 48) as excluding Artinsk and lower beds, and remembrance of this usage modifies the meaning of King's (*op. cit.*) citation. The Hueco limestone contains several species belonging to *Triticites*, *Schwagerina*, *Pseudoschwagerina*, *Schubertella*, and other genera that support correlation with the Wolfcamp beds (Dunbar and Skinner, 1937, pp. 720, 721).

The placement of the lower Permian boundary in trans-Pecos Texas according to different authors is shown diagrammatically in Figure 4. In all publications this boundary has been drawn at the base of the Wolfcamp formation, but until the Pennsylvanian age of the *Uddenites* fauna was determined and the definition of the Wolfcamp revised, the west Texas boundary was equivalent to a position in the basal Cisco of north Texas. This is a lower position than has been advocated by anyone in the north Texas region.

Western United States.—There is little value for purposes of this paper in an exhaustive review of usage in definition of the Pennsylvanian-Permian boundary in the western United States. This is partly due to the wide variation in the nature of the stratigraphic succession, partly to the lack of discovered diagnostic fossils in many sections, and partly to insufficient knowledge. Study of the western Permian undoubtedly has significance in work to determine major stratigraphic boundaries that are applicable to late Paleozoic rocks, but age determinations are based largely on correlation with standard sections in the western Texas and Mid-Continent regions.

The boundary between the Carboniferous and Permian systems throughout much of New Mexico appears to belong at the base of the Abo sandstone, which in most places lies unconformably on the Magdalena limestone, of Pennsylvanian age (Darton, 1926, p. 833; 1928, p. 20). Locally, as in the Pedernal, Zuni, and Nacimiento ranges, the Abo overlaps onto pre-Cambrian rocks (Fig. 5), and in the southern part of the Sacramento Mountains it is overlapped by younger Permian rocks of the Chupadera formation. The Abo has yielded fossils classed as Lower Permain (Darton, 1928, p. 21) and the reported occurrence of fossils in this formation regarded as indicating

Pennsylvanian age (Böse, 1920; King, 1934, p. 747; Romer, 1935, p. 1634) appear to be untrustworthy (Miller, 1932, p. 59; P. B. King writes, September 27, 1939, corroborating Miller's conclusion that the ammonoid-bearing beds near Tularosa are not true Abo). King (1934, p. 746) indicates equivalence of the Abo to part of the Hueco limestone, which contains *Pseudoschwagerina* (Needham, 1937, p. 54) and writes (letter, September 27, 1939) that "present field evidence is definitely in favor of the view that the Abo is of Wolfcamp age." The topmost beds of the Magdalena appear to represent horizons in the Virgil series in some places but belong to the Missouri or older divisions in others (Needham, 1937, p. 15).

The oldest strata assigned to the Permian in northeastern Arizona, southwestern Colorado and southern Utah are designated as the Rico formation (Baker and Reeside, 1929). Marine fossils of the Rico, which are not very diagnostic, were long considered to be Pennsylvanian but are now regarded as Lower Permian. Stratigraphic relations indicate correlation of the Rico with Wolfcamp strata, such as the Abo and Hueco in New Mexico, and with the lower part of the Supai formation in the Grand Canyon district (Baker and Reeside, 1929, p. 1441). The Rico lies parallel with, but apparently disconformably on, the Hermosa formation, of Pennsylvanian age. Most of the Hermosa fossils observed by the writer are Des Moines species, but beds of Missouri and possibly Virgil age may be present. Pennsylvanian limestone, termed Magdalena by Darton (1925, p. 73), occurs locally as a thin remnant disconformably below the Supai formation in the Grand Canyon. The basal Supai has yielded plants that are identified as early Lower Permian by David White (Baker and Reeside, 1929, p. 1440). Strata of northeastern Arizona and southern Utah, equivalent to the Supai, are designated as Cutler. A recent detailed study of the Kaibab and Toroweap formations, which lie above the Coconino sandstone in northern Arizona and southern Utah, has led to correlation of them with the San Andres limestone of New Mexico and upper part of the Leonard formation of Texas (McKee, 1938, p. 217). In southern Arizona, the lower part of the Naco limestone contains an early Pennsylvanian fauna (Girty, cited by Ransome, 1916, p. 149) but an upper horizon in the Naco yields Lower Permian fossils (Darton, 1925, p. 71; R. E. King, 1931, p. 25); presumably there is a disconformity between the Pennsylvanian and Permian rocks.

A very interesting succession of Carboniferous and Permian deposits is found in southern Nevada (Fig. 5). Near Las Vegas an apparently conformable succession of marine beds, mostly limestone,

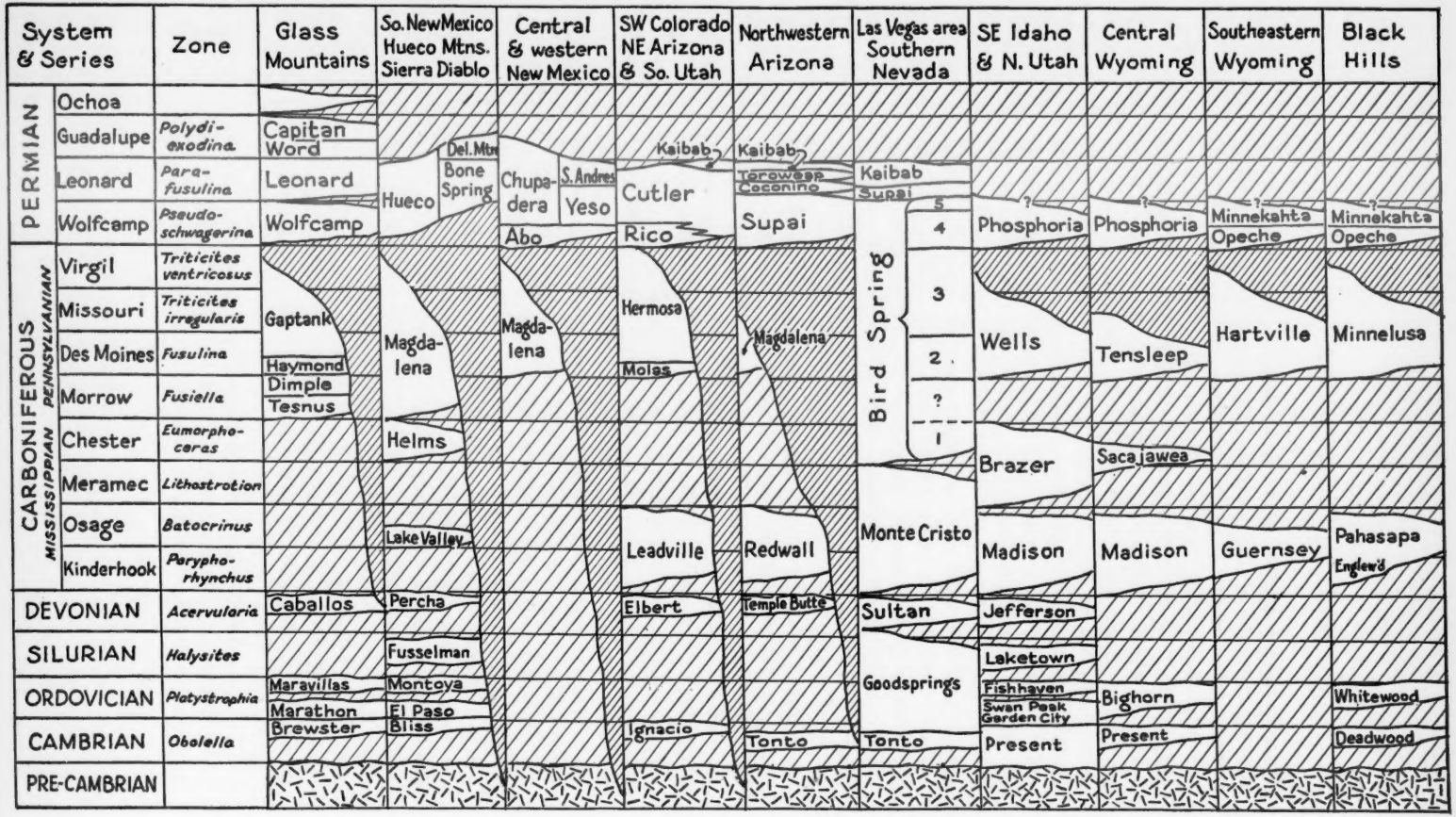

FIG. 5.—Diagram indicating succession and stratigraphic relations of Paleozoic formations in various western states. Breaks in succession are indicated by oblique-ruled areas, that beneath zone of *Pseudoschwagerina* being differentiated by closer spacing of lines.

is designated as the Bird Spring formation, in places 5,200 feet thick, and above this with apparent conformity come Supai red deposits (1,200 feet) and Kaibab limestone (600 feet). The lower 700 feet of the Bird Spring strata contain a Chester fauna, the next 1,600 feet bear *Fusulinella* and *Triticites*, being identified as lower and upper Pennsylvanian; the upper 2,950 feet contain *Schwagerina* and *Pseudoschwagerina* and these beds are correlated with Wolfcamp and Leonard divisions of the western Texas section (Longwell and Dunbar, 1936, p. 1202). Lines of division are drawn on the basis of observed distribution of fossils, but it is possible that further field study will show existence of physical breaks. Bearing on placement of formations of the Grand Canyon section in the standard Permian divisions, as defined in western Texas, it is to be noted that if the upper Bird Spring limestone is lower Leonard, the succeeding beds identified as Supai and Kaibab must be Leonard or younger. The Kaibab of the type region has been rather confidently correlated with the San Andres and upper Leonard, as just noted. There is no reason to doubt correlation of the beds called Kaibab in the Las Vegas region with type Kaibab. The Muddy Mountains contain 2,000 feet or more of limestone (Callville) that is identified as Pennsylvanian, followed by sandstone and redbeds correlated with the Supai, but the section is incomplete and the position of the basal Permian boundary is indeterminate (Longwell, 1928, p. 21).

Far to the west, in northern California, the McCloud limestone, bearing fusulinids of the *Pseudoschwagerina* zone, rests unconformably on the Lower Carboniferous Baird limestone (Dunbar, letter, August 25, 1939).

In northern Utah, southern Idaho and much of Wyoming, the Permian is represented by the Phosphoria formation, which contains a highly specialized fauna that reflects an unusual environment. The Phosphoria rests disconformably on beds variously called Weber quartzite, Wells formation, Quadrant formation, and Tensleep sandstone, all of which have yielded Pennsylvanian faunas. For the most part, beds younger than the Des Moines series are lacking (Girty, in Mansfield, 1927, p. 73; C. C. Branson, 1939, p. 1223), and at least locally there are distinctive types of Des Moines fossils immediately below the Phosphoria (C. C. Branson, 1939, p. 1204). Girty (Mansfield, 1927, pp. 78–81) concluded that his first published identification (Girty, 1910, p. 8) of the age of Phosphoria beds as upper Pennsylvanian was erroneous and that on the basis of more complete evidence the fauna should be classed as Lower Permian, equivalent to the Artinskian of Russia. C. C. Branson (1936) concurs in this view, though E. B. Branson (1916) had earlier insisted on the basis of fish

remains that the Phosphoria was Upper Carboniferous. J. S. Williams (1932, Pl. 5) has indicated assignment to the Lower and Middle Permian. R. E. King (1931, pp. 30–33) concluded that the Phosphoria was the approximate time equivalent of the Word formation, and that it should be classed as Middle Permian. Miller and Cline (1934, p. 283) identified Phosphoria ammonoids from beds 150 feet above highest exposed Pennsylvanian, considering these fossils as diagnostic of the Middle Permian. H. D. Thomas (1934, pp. 1662–63) has reviewed the known stratigraphic relations and faunal evidence without reaching a definite opinion. A disconformity between older and younger parts of the Phosphoria formation has not been recognized. If the Phosphoria is not older than the Leonard series (J. E. Adams and others, 1939, p. 1675) and if the next underlying strata do not include representation of the Wolfcamp series, the region under consideration offers no direct evidence on the precise horizon of the Carboniferous-Permian boundary. In some sections, as has been noted, all of the upper Pennsylvanian (Missouri and Virgil series) and possibly the Wolfcamp series are missing. J. S. Williams (letter, September 30, 1939) states that "evidence is at hand to strongly suggest that the *Pseudoschwagerina* zone is in the upper part of the 'indivisible' Weber." This can not be given any weight, however, until specific information is available.

In southeastern Wyoming and the Black Hills region of South Dakota, the Hartville and Minnelusa formations, containing Pennsylvanian fossils, are overlain by unfossiliferous red shale (Opeche) and dense limestone (Minnekahta) that are considered to represent an undetermined part of Permian time. The lower half of the Hartville contains a Des Moines fauna and the upper half includes a division with Missouri and Virgil fossils that is disconformably overlain by barren beds, mainly sandstone, doubtfully referred to the Permian (Condra and Reed, 1935; Thompson, 1936). The lower part of the Minnelusa formation is undoubtedly of Des Moines age (Dillé, 1930; Brady, 1931) and the upper part is correlated with the Missouri series (Brady, 1931).

Definition of the lower boundary of Permian deposits along the flanks of the Rockies in southern Wyoming and Colorado, involves study of the relations of barren or sparsely fossiliferous formations such as the Satanka, Casper, Lykins, Lyons, and Maroon deposits, and it does not seem profitable to review evidences from this region.

Appalachian region.—The only part of the Appalachian region containing deposits that are believed to belong to the Permian is the area of Dunkard outcrops in southwestern Pennsylvanian and

adjoining states. Formerly designated as the Upper Barren Coal Measures, these rocks were included by Williams (1891) in his original definition of the Pennsylvanian series. Fontaine and I. C. White (1880), however, had previously identified some 28 species of Dunkard plants as types occurring in the Permian of western Europe and had classed all of the beds of this group as Permian. Paleobotanical studies of the Dunkard and underlying Carboniferous divisions by D. White (1903, p. 538) led to conclusions supporting reference of at least the major (upper) part of the Dunkard to the Lower Permian. The flora of the lower half of the Washington formation (lower of the two main divisions of the Dunkard), White considered transitional from Coal Measures to Permian, but upward from the horizon of the lower Washington limestone, the presence of typical Rotliegende plants, such as *Callipteris conferta*, *Callipteridium*, and *Equisetites rugosus*, was interpreted to signify definitely that the middle and upper Dunkard deposits should be designated as Permian. Stevenson (1907, pp. 95–141) later described the Dunkard of the type region in considerable detail, reviewed the paleontologic studies that had been made, and then, without explanation, placed the Dunkard at the top of the Pennsylvanian (Stevenson, p. 178), apparently meaning that the uppermost Pennsylvanian is equivalent in age to Lower Permian beds of Europe. On the basis of vertebrate evidence, Romer (1935, p. 1632) correlates the Dunkard with the Council Grove, Chase, and possibly Sumner groups of Kansas, and the Wichita and Wolfcamp beds of Texas; he would assign all of the Dunkard beds to the upper Pennsylvanian (p. 1629). D. White, in 1936 (p. 690), classed all of the Dunkard as Permian, although ten years previously (1926, p. 1053) he apparently did not consider the lower Dunkard as definitely belonging to the Permian. Darrah (1934, p. 451; 1937, p. 128), on the basis of fossil plants, draws the Pennsylvanian-Permian boundary at the contact of the Washington and Green formations, in the middle part of the Dunkard.

PALEONTOLOGIC RELATIONSHIPS OF CARBONIFEROUS-PERMIAN BOUNDARY AS VARIOUSLY DEFINED

It is needful to scan at least the more significant paleontologic relationships of various placements of the boundary at the base of the Permian. Does the position of this line in any given case have validity in terms of clearly marked differences of the faunas or floras observed in the beds immediately below and above the boundary? Which one among the several boundaries that have been used has strongest support from paleontologic considerations?

Northern Mid-Continent region.—The lowest position of the Carboniferous-Permian boundary that has been designated in the northern Mid-Continent is marked by the disconformity at the base of the Admire group and top of the Wabaunsee group (restricted). The highest position that has been proposed is in the midst of the Wellington shale, just above the Carlton limestone member. Between these limits the boundary has been placed in various positions at different times, most generally at the horizon of the Cottonwood limestone.

The Wabaunsee group belongs in the zone of *Triticites* and is characterized by a normal Upper Carboniferous assemblage of invertebrates and by floras of definite Stephanian type. Among Wabaunsee ammonoids from Kansas are *Vidrioceras irregulare* Böse, *Glaphyrites kansasensis* (Miller and Gurley), *Wiedeyoceras pingue* A. K. Miller and Cline, and *Neoaganides grahamensis* Plummer and Scott, all of which occur in Texas in the *Uddenites schucherti* zone, belonging at the base of the Cisco group of north Texas and the top of the Gaptank formation of west Texas.

The fauna of the beds between the base of the Admire group and the Carlton limestone resembles that of the Wabaunsee group and underlying upper Pennsylvanian beds in many features, and a majority of the invertebrate species in the higher horizons is unquestionably derived from well known Pennsylvanian forms, in numerous cases being identified specifically with them. There is a gradual change that is accentuated by disappearance of old species and appearance of some new genera and species. The progressive nature of faunal modification is that which may be expected in a conformable succession of dominantly marine strata. *Triticites* persists in the lower part of this succession, chiefly in beds below the Cottonwood, but the species are mostly different from those in recognized Pennsylvanian formations. *Schwagerina* ("*Pseudofusulina*") appears in the Americus limestone and is extremely abundant in the Cottonwood limestone. *Schwagerina* and *Paraschwagerina* are found in the Neva limestone, and the former genus is extremely abundant in the Cottonwood limestone. *Pseudoschwagerina* occurs in the Florence flint. Broadly defined to include conformable beds below and above those that contain specimens of *Pseudoschwagerina*, it seems proper to consider all of the Admire, Council Grove and Chase groups as belonging to the *Pseudoschwagerina* zone. The lower boundary of the Permian in Kansas has most commonly been placed below the base of the *Pseudoschwagerina* zone, narrowly defined; all of the assigned positions of this boundary, except Romer's, have been located within or at the base of the *Pseudoschwagerina* zone, broadly defined. This

has no necessary significance as to the correctness of any indicated position of the boundary or incorrectness of any, but it shows the nature of usage.

Schwagerina emaciata (Beede), associated with *Schubertella kingi* Dunbar and Skinner, occurs in the Cottonwood limestone of Kansas and Nebraska, in the Coleman Junction limestone (at the top of the Putnam formation) in north Texas, and in the Hueco and Wolfcamp formations of west Texas, indicating close correlation of these beds (Dunbar and Skinner, 1937, p. 635). Just above the Cottonwood limestone are found the ammonoids, *Artinskia whortani* A. K. Miller (1936), and *Metalegoceras* sp., which correspond to the *Artinskia adkinsi* zone, just above the Coleman Junction limestone and in the Wolfcamp, which also includes *Properrinites* almost identical with *Properrinites plummeri* Elias from the Neva. These support and confirm correlations of the Cottonwood, Coleman Junction and a part of the Wolfcamp, already indicated.

Among fossil plants, *Callipteris conferta*, *Taeniopteris*, *Lebachia* (*Walchia*), *Odontopteris*, and others, which occur at the Wreford and higher horizons in Kansas, are considered by Sellards (1909) and D. White (1926, p. 1057) as characteristically Permian, and White (*ibid.*) interprets other floras as low as the Americus as also referable to the Permian. In the Wellington shale, below the top of the Carlton limestone, Sellards (1909, p. 467) and D. White (1926, p. 1058) have reported a flora containing *Callipteris*, *Taeniopteris*, *Glenopteris*, *Ullmania*, and other plants that "point clearly to a stage high in the Lower Permian" (White). In northern Oklahoma, at an approximately equivalent horizon, *Gigantopteris* occurs, and this is found with other "diagnostic" Permian plants in the upper Wichita beds of north Texas.

Romer's designation of the lower Permian boundary in Kansas is evidently based on his correlation of the Carlton limestone with the Beaverburk limestone, upper Belle Plains formation, of Texas. Known vertebrate remains from the Big Blue series of Kansas and redbeds of equivalent age in Oklahoma, representing about a dozen genera, Romer (1935, pp. 1630–32) correlates with north Texas horizons, mostly in the Wichita group.

North-central Texas.—In north Texas, the lowest suggested position of the Pennsylvanian-Permian boundary is at the disconformable base of the Thrifty formation, which is approximately 300 feet above the position of the *Uddenites schucherti* zone. J. W. Skinner (letter dated October 3, 1939) states that fusulinids of the Thrifty formation are only slightly different from Graham forms, which are undoubtedly

Pennsylvanian, but they are readily distinguished from Harpersville species. The lower Permian boundary has also been drawn in the middle part of the Harpersville formation, about 500 feet above the *Uddenites schucherti* horizon, because fusulinids correlated with those of the Neva limestone (including *Schwagerina*) occur just above this line (Roth, 1931). *Schwagerina* and *Pseudoschwagerina* are found in the Moran formation and are the basis for designation of the lower limit of the Permian at the base of this formation (Sellards, 1932, p. 140, who, however, erroneously refers to *Paraschwagerina*). The Coleman Junction limestone, at the top of the Putnam formation and just below the Wichita group as defined until recently, contains fossils corresponding to guide forms of the Cottonwood limestone, as already noted; trustworthy fusulinid and aommnoid evidence indicates equivalence of the Coleman Junction and part of the Wolfcamp beds.

The Wichita group, especially the Belle Plains formation, which Romer classes as its topmost division, has yielded many fossil plants (*Callipteris, Lebachia, Gigantopteris,* and others) that "put beyond question the Lower Permian age" of these strata (D. White, 1926, p. 1060). The abundant vertebrate fauna of the Wichita deposits (defined according to Romer) is not sharply differentiated from known forms occurring in subjacent Cisco horizons, but is rather clearly distinct from the succeeding Clear Fork assemblage (Romer, 1935, pp. 1606–51). Related "Cisco" and "Wichita" vertebrate faunas, as designated by Romer, are included together in the Wolfcamp series of north-central Texas by M. G. Cheney (1940).

The *Pseudoschwagerina* zone in north Texas may be considered to include the Admiral, Putnam, Moran, and probably the Pueblo and upper Harpersville formations. If this is proper, as it appears to be, then all of the published definitions of the basal Permian boundary in north Texas, except Romer's and Dumble's, which place this line very high, and the writer's suggested placement (Moore, 1935) at the base of the Thrifty, which is too low, are within or at the base of the zone of *Pseudoschwagerina.*

Western Texas.—No one now contends that the lower boundary of the Permian rocks belongs below the zone of *Uddenites* in the trans-Pecos Texas section, for the position of this zone in the lowermost Cisco beds is established and the upper Pennsylvanian age of the lower Cisco beds is agreed. The boundary at the base of the Wolfcamp (restricted) separates the Pennsylvanian *Uddenites* beds from the zone of *Pseudoschwagerina,* which contains, along with this genus, *Schwagerina, Paraschwagerina,* and advanced forms of *Triticites;* also *Artinskia, Properrinites,* and other ammonoids. According to

A. K. Miller (letter, September 8, 1939), ammonoid genera that occur in Upper Carboniferous but not in the Wolfcamp beds include *Uddenites, Prouddenites, Neodimorphoceras, Gonioloboceras, Shumardites*, and others: among genera that first appear in the Wolfcamp are *Propinacoceras, Paragastrioceras, Pseudogastrioceras, Metalegoceras, Stacheoceras, Popanoceras*, and *Properrinites*. A single "Lower Permian" specimen is reported by Miller to be identified as belonging to *Schistoceras*, a genus that is abundant in upper Pennsylvanian rocks and characteristic of the Upper Carboniferous. Ammonoid genera that cross the boundary line at the base of the Wolfcamp beds include *Neopronorites, Daraelites, Eoasianites, Agathiceras*, and *Peritrochia*. According to Miller (1938, p. 1017) placement of the Carboniferous-Permian boundary at the base of the Wolfcamp is compatible with the ammonoid evidence, but this evidence does not establish the boundary. The Leonard formation, at the base of which Romer would draw the lower Permian boundary, belongs to the zone of *Parafusulina*, although the lower 600–700 feet contain only rare specimens of this genus and have an abundance of *Schwagerina* (J. W. Skinner, letter dated October 3, 1939). The Leonard contains ammonoids, brachiopods, and other fossils that are readily distinguished from those of the Wolfcamp beds.

Western United States.—Rocks containing fusulinids of the zone of *Pseudoschwagerina* occur in south-central New Mexico (Hueco), southern Nevada (Bird Spring) and northern California (McCloud). The next underlying rocks contain fossils of varying age, from Cambrian to upper Pennsylvanian, and in places there are pre-Cambrian rocks next below the *Pseudoschwagerina* zone. Elsewhere in the western states invertebrate faunas that lack fusulinids occur in marine formations such as the Rico, Toroweap, Kaibab, and Phosphoria, and permit correlations that are mostly rather insecure. Evidence indicates that these deposits belong partly to the zone of *Pseudoschwagerina* and partly to younger divisions. The immediately subjacent strata range in age from lower to upper Pennsylvanian. Continental formations such as the Supai, Hermit, and Cutler have yielded some plant remains that are interpreted to indicate Lower Permian. The rocks beneath these non-marine strata range in age from pre-Cambrian to upper Pennsylvanian (excluding marine beds classed as Permian).

Appalachian area.—As already noted, the Dunkard beds have been assigned wholly or partly to the Permian because plants of Autunian type make appearance, sparingly in the lower strata and in large numbers in upper beds. Correlation with plant-bearing deposits

of the Mid-Continent region indicates correspondence with the part of the Big Blue series below the top of the Chase group (D. White, 1936, p. 690). The Waynesburg flora, at the base of the Dunkard, is considered by White (1926, p. 1053) comparable to that of the Lebach or Cusel beds of the lower Rotliegende, and higher plant assemblages are thought to be as late as the horizon of the beds in the basin of Brives (Autunian) of France, Lower Permian.

General remarks.—This summary indicates that in early stratigraphic studies determination of the boundary at the base of the Permian rested primarily on the judgment of the Permian aspect of one or more groups of fossils,—invertebrates, vertebrates, and plants. The presence of hold-overs from underlying horizons was accounted altogether expectable, and significance was assigned to observed new components rather than residual elements in the biota. A line of division was chosen at some point in the conformable succession of beds, and it is evident that a variety of factors influenced this choice, making inevitable a fluctuation in the position of the boundary as determined by different workers or by the same worker at different times. Also, it is important to note that apparent divergence in the results obtained from study of marine invertebrates, and the fossils of continental deposits, both vertebrates and land plants, is without doubt due in large part to a lack of realization of the significance of facies or to insufficiency of evidence for measuring the effects of environment. As indicated by the typical "Permian" flora from upper mid-Pennsylvanian (upper Missouri) rocks of Kansas (Moore, Elias, and Newell, 1936) and by analysis of other floras according to their climatic and ecologic setting (Elias, 1936), there can be little doubt concerning possibility (or probability) of the appearance earlier in some sections than in others of plants and land vertebrates that are regarded as characteristically Permian. Evidences marshaled by Case (1915, 1919, 1922, 1924) and Romer (1935) along this line are very convincing. Thus, full reliance in definition of stratigraphic boundaries, such as the lower limit of the Permian, should not be placed on land plants or vertebrates alone, and it may be concluded from indications of the greater uniformity of marine conditions, affecting intermigration of organisms, that fossiliferous marine sections offer best standard sections for definition of paleontologic zones and boundaries.

A review of American usage shows that part or all of the zone of *Pseudoschwagerina*, as now recognized, has been classed as belonging to the Permian by almost every geologist, from earliest time to the present. Increased stratigraphic knowledge of the late Paleozoic rocks

and fossils, including especially distribution of fusulinids and ammonoids, has furnished grounds for a growing tendency to define the base of the zone of *Pseudoschwagerina* as the Carboniferous-Permian boundary. This is strengthened by observation of a profound physical break at the base of the Wolfcamp deposits. The proposal to place this boundary above the Wolfcamp and equivalent beds is supported by usage in Russia, but it does not accord satisfactorily with usage in western Europe, where the line at the base of the Rotliegende (Autunian) almost certainly does not represent a horizon as high as the top of the *Pseudoschwagerina* zone.

STRUCTURAL AND STRATIGRAPHIC RELATIONSHIPS OF CARBONIFEROUS-PERMIAN BOUNDARY

Supplementing in important manner the consideration of paleontologic evidences,—indeed, largely controlling them,—are the structural and stratigraphic relationships of any suggested line of division between rocks classed as Carboniferous and Permian. Structural relationships refer to the presence or absence of an unconformity and the parallelism or angular discordance of beds above and below the boundary. Stratigraphic relationships might be defined to include structural features, but as here used, reference is made to the nature of regional persistence or variation of conditions at an indicated horizon, the significance of lithologic characters, evidences of offlap or overlap, and position of paleontologic zones.

In the northern Mid-Continent area, the Big Blue series lies parallel with the upper Pennsylvanian beds. The thickness and lithologic character of groups, formations, and members are remarkably uniform for great distances. Evidences of cyclic sedimentation are clearly defined, indicating very regularly recurrent oscillations of shallow seas. Thinning of shale beds and increase of calcareous deposits westward in the direction of the central part of the basin of deposition give rise to the "big lime" encountered in wells. No disconformities are found anywhere in the Big Blue section, but such a break is identified at the base, below the Admire group. Altogether, no basis of any sort can be found in the structural and stratigraphic relationships of the Big Blue beds for definition of any horizon except the disconformity at the base as a boundary of major importance. If some bed within the series is chosen to mark such a boundary, there is no known physical evidence for selecting it.

Oklahoma and the northern part of the north-central Texas district contain very extensive redbeds deposits that are proved to be contemporaneous with Big Blue marine sediments in the north and

Wichita marine sediments in the south. Beneath the redbeds that may be Permian are redbeds that grade laterally into upper Pennsylvanian marine deposits. A disconformity equivalent to that at the base of the Admire group in Kansas and Nebraska has been reported by Darsie Green to be traceable from northern Oklahoma to the flanks of the Arbuckle Mountains. Disconformities at higher horizons, as at the base of the Duncan and Garber sandstones and the base of the Whitehorse sandstone, are recognized and there are probably others that are of stratigraphic significance. Whatever the relation of these lines of divisions in the redbeds may have to definition of the lower Permian boundary, the more conclusive evidences are probably to be sought in the adjoining districts of dominantly marine sedimentation. Nevertheless, the land plants and vertebrate remains, especially in north Texas, must be considered in relation to physical breaks in the rock succession.

The Wichita, Clear Fork, and higher marine strata of north-central Texas form a regular succession that lies parallel with the upper Pennsylvanian Cisco beds and apparently conformable upon them. Evidences of disconformities are found in the middle of the Harpersville formation, at the base of the Avis conglomerate in the Thrifty formation, and at some other horizons. Paleontologic evidence suggests that the middle Harpersville horizon may correspond to the disconformity at the base of the Admire group, but the Texas equivalent of this break, if existent, may be still lower. No physical evidence is seen for placement of the lower Permian boundary at the base of the Moran formation, the top of the Coleman Junction limestone, or any other particular bed in the regularly conformable succession of shales and limestones.

The Wolfcamp and equivalent Hueco limestone of trans-Pecos Texas rest disconformably or with profound angular unconformity on beds ranging in age from upper Pennsylvanian to pre-Cambrian (P. B. King, 1934). The break beneath the *Pseudoschwagerina* zone in this region is unquestionably one of great importance. Whether or not the unconformity is defined as marking the Carboniferous-Permian boundary, according to current usage, the structural and stratigraphic relations indicate that this is a more evident line of division than any other in the late Paleozoic section of the region. A disconformity separates the Wolfcamp from overlying Leonard beds, and locally there are thick deposits of conglomerate at the base of the Leonard.

A large stratigraphic hiatus beneath strata of the zone of *Pseudoschwagerina* in the western United States is evident in many areas

(see Fig. 5), but in a number of places the boundary between this zone and older rocks is not sharply defined. If the Kaibab, San Andres and equivalent western formations are rightly correlated with the Leonard and if underlying strata are correctly regarded as equivalent to Wolfcamp beds, no place is observed where a well marked unconformity separates them.

The Dunkard group follows the Monongahela beds of the upper Pennsylvanian with parallel bedding. A disconformity occurs at the base of the Waynesburg sandstone, just above the base of the Dunkard, as shown by local variations in thickness and channeling of the underlying Cassville shale (Stevenson, 1907), but no special importance can be assigned to this, for there are disconformities beneath numerous other sandstones in the section. Also, the Cassville shale contains the lowest Dunkard flora of Permian aspect (D. White, 1926, p. 1053). The Lower Washington coal horizon, in the middle part of the lower Dunkard, where White (*ibid.*) identifies definitely Permian plants, and the still higher contact at the base of the Greene formation, where Darrah (1934) draws the basal Permian boundary, are parallel with lower beds and apparently conformable.

COMPARISON OF CARBONIFEROUS-PERMIAN BOUNDARY IN EUROPE AND NORTH AMERICA

The *Pseudoschwagerina*-bearing beds of the Russian platform and Urals geosyncline are correlated confidently with marine deposits in the United States belonging to the Big Blue, Wichita, and Wolfcamp (Beede and Kniker, 1924; Plummer and Scott, 1937, p. 395; Dunbar, 1940; Schuchert, 1935; Elias, 1935; p. 370; A. K. Miller, 1936, 1937). The zone of *Pseudoschwagerina* is designated as the Sakmarian series in the southern Urals, and although some beds containing this fusuline have been classed as Artinskian, Ruzencev (1936) proposes restriction of the Artinskian on a paleontologic basis to exclude such beds. Lower Artinskian beds near Artinsk are correlated by Plummer and Scott (1937, p. 392) with middle Wichita (Admiral or slightly higher) beds on the basis of ammonoids; Böse (1917) regards the Artinsk as equivalent to the Leonard and younger rocks of West Texas, the Wolfcamp ammonoids (including the *Uddenites* fauna, as interpreted by him) indicating pre-Artinskian age. Elias (1935) places the American equivalent of the base of the Artinskian at the top of the Belle Plains formation in North Texas, where Romer (1935, p. 1629) places the dividing line between the Wichita and Clear Fork groups. Omitting numerous other citations and discussion of details, there seems to be wholly adequate basis and general

agreement to support correlation of the Sakmarian and equivalent beds of Russia with strata called Big Blue (Council Grove group, Chase group, probably Admire group, and possibly Sumner group) in the northern Mid-Continent region, the Wichita group (possibly excluding the Lueders and Clyde formations at the top) and probably the Pueblo and upper Harpersville formations of the Cisco group in north-central Texas, and the Wolfcamp beds of western Texas. There is some difference of opinion whether the Artinskian (as restricted by Ruženčev) of Russia corresponds in part to beds included in the upper Big Blue and Wichita that are already indicated as probably Sakmarian, or is confined to higher horizons. In the trans-Pecos Texas region, the base of the Artinskian appears to belong not lower than the base of the Leonard.

Comparison of the Upper Carboniferous and Lower Permian sections of western Europe with those of North America indicates placement of the lower Rotliegende or Autunian (Lower Permian) boundary in the middle part of the Dunkard group or somewhat lower in this group (D. White, 1926, 1936; Darrah, 1934, 1937), at or near the base of the Council Grove group in the Big Blue series (D. White, 1926, 1936; Elias, 1937), and in the lower part of the Wichita group at a horizon not precisely indicated (D. White, 1926, 1936). In all of these sections, both American and European, the highest Stephanian plant zones are generally very little older than the lowest plant-bearing zones classed as belonging to the Permian. On the basis of interbedded marine strata containing *Pseudoschwagerina* and other fossils of this zone and nonmarine strata containing lower Rotliegende (Autunian) plants, equivalence in age is clearly indicated for at least part of these divisions. The Sakmarian marine beds, with *Pseudoschwagerina*, rest on limestones of the *Triticites* zone, just as strata of the Big Blue and Wichita groups, with *Pseudoschwagerina* and Rotliegende plants, overlie Pennsylvanian beds with abundant *Triticites*. Stratigraphic sequences are the same. Finally, it may be noted that the interbedded marine and non-marine plant-bearing zones in the upper part of the Donetz basin section of Russia show confirmatory evidence (Zalessky, 1938).

Following the studies of Karpinsky and Tschernyschew, almost everyone has come to accept definition of the Carboniferous-Permian boundary in Russia as belonging above the "*Schwagerina* beds" and below the Artinskian. A number of geologists have classed the Artinskian as Permo-Carboniferous, thinking that it is transitional between true Carboniferous and true Permian, but this view has been discarded. Accepting definition of the lower Permian boundary

at the base of the Artinskian, as fixed by long usage, Romer (1935, p. 1653) concludes that this boundary should be drawn in North America at the base of the Leonard, base of the Clear Fork, a little below the base of the Cimarron, and above the highest remaining Dunkard strata. These correlations, which have been previously noted, appear to be made soundly, and Romer's application of them to revision of the Carboniferous-Permian boundary in North America should be held correct and fully acceptable *if* definition of the position of this boundary remains fixed in terms of the Russian section above the zone of *Pseudoschwagerina*, at the base of the Artinskian. Acceptance of this boundary, however, seems clearly to call for transfer of lower Rotliegende (Autunian) beds in western Europe from the Lower Permian, where these rocks have been placed by all, to the Upper Carboniferous. It is apparent, also, that in North America similar upward revision of the Carboniferous-Permian boundary requires in all districts transfer to the Carboniferous of strata that have been considered universally as belonging in the Lower Permian. Very compelling reasons must be advanced to win general acceptance of such drastic changes, and strong resistance to this sort of revision may be expected from Europeans as well as from Americans.

Study of the sections of marine Carboniferous and Permian strata in Russia, both by Europeans and Americans, has led during the last 15 years to revision of the Carboniferous-Permian boundary that places this line at the base of the zone of *Pseudoschwagerina* (Sakmarian). Paleontologic evidences and physical criteria are cited in support of this lower position of the boundary (see Ružencev, 1936, 1937; Dunbar, 1940, and others). Much more significant than conditions in the Russian area alone are the facts that in several parts of the world rocks of the *Pseudoschwagerina* zone, or equivalent to it, are separated from older formations by an important stratigraphic break, and that in many regions these rocks of Sakmarian age have long been classified as Lower Permian by practically all geologists. As matters stand, division exists among Russian geologists as to placement of the lower Permian boundary. Probably a majority has not accepted the pre-Sakmarian position proposed by Ružencev (see Williams, 1938), although Dunbar, in a recent letter, contests this appraisal of Russian opinion. In any case, this means little, since such questions surely are not settled by simple vote nor fixed even by uniform previous usage. Usage has weight, for it is supported almost invariably by sound reasons, and it builds stability rather than chaos; nevertheless, it can not be allowed to sanctify any dictum. Long standing designation of the western European redbeds (Rotlie-

gende) as Permian, and similar long standing assignment of American deposits to the Permian, make revision of the position of the boundary in Russia to include correlative beds in the Permian extremely desirable.

It is pertinent to quote a summary by Dunbar (letter to C. W. Tomlinson, August 25, 1939).

The "*Pseudoschwagerina* complex" marks a distinct horizon that can be recognized in most parts of the world where fusulines are represented. This fact Madam Rauser-Chernoussova has clearly stated, and I believe all will agree to it; it is the horizon of the Wolfcamp in America, the Sakmarian in Russia, the Schwagerinakalk of the Alps, the Chuanshan of south China and its equivalent in Indo-China. In many parts of the world it follows a great hiatus. In the southwestern part of the U.S.A. it is separated from the Pennsylvanian beds by profound unconformity in the Glass Mountains, and by angular disconcordance of varying degrees farther west in Texas and New Mexico. These beds overlap onto the pre-Cambrian in west Texas and in places in New Mexico, and in northern California rest disconformably on the Lower Carboniferous (i.e. McCloud limestone on Baird limestone). Over a vast area in the Orient, the Chuanshan and its equivalents rest on beds of Moscovian (Des Moines) age or older. In south China it is the Chuanshan on the Huanglung limestone, and in Indo-China it is the equivalents of these units. Fromaget has shown that there was a great change in paleogeography and extensive igneous activity in Indo-China during this interval. In short, the horizon represented by the Missouri and Virgil series of the U.S.A. is missing throughout China and Indo-China. In South America this horizon rests upon much older rocks. The situation in the Permian basin of the U.S.S.R. is discussed in detail in the writer's manuscript on "The Type Permian." The *zone of Triticites* is well represented there and probably no great hiatus exists over the deeper part of the basin between the base of the Middle Carboniferous and the top of the Permian. In this respect the situation resembles that in the northern mid-continent region.

Throughout its whole sweep, the *zone of Pseudoschwagerina* is characterized not by one genus or one species, but by a complex of species of the genera *Schwagerina*, *Pseudoschwagerina* and *Paraschwagerina*. This represents a great evolutional outburst in the family Fusulinidae. These forms appear abruptly above the hiatus noted above and become "world-wide" in their distribution. The underlying strata, which constitute our upper Pennsylvanian (i.e. Canyon and Cisco, or Missouri and Virgil) having a thickness of several hundred feet, are characterized by various species of the genus *Triticites*, with none of the genera mentioned above. The *zone of Triticites* is equally recognized in other parts of the world wherever its horizon is represented by marine strata. It is true that the genus *Triticites* holds over into the *zone of Pseudoschwagerina* and gradually dies out, but with the local exception noted by Rauser-Chernoussova, I do not know of any species which crosses that boundary. The faunal break above the *zone of Pseudoschwagerina* is one of gradual restriction and a very gradual evolution of the septal folds from the stage of *Schwagerina* s.s. to that of *Parafusulina*. It is my measured judgment that, considering the world in the large, the fusuline faunal break, like the stratigraphic hiatus, is far greater below than above the *zone of Pseudoschwagerina*.

CONCLUSIONS

The discussion that has been presented indicates the basis for several conclusions that may be listed as follows.

(1) A geologic system is a major stratigraphic division comprising the rocks formed during a relatively long time span, called a period. Remains of life found in each fossil-bearing system exhibit features that collectively characterize it and distinguish it from other systems.

(2) Numerous stratigraphic divisions, overlapping and mutually conflicting, have been proposed as geologic systems. Some of these, like Cretaceous, Carboniferous, and Permian, are familiar to geologists of the world; some, like Fengninnian, Ozarkian, and Kamilaroi, are not generally recognized by geologists of the world.

(3) Wide acceptance of systemic terms, serving to promote understanding of age determinations of rocks in all lands, is an important factor in deciding what divisions are best fitted for use in standard classification of geologic columns.

(4) The Carboniferous system, including post-Devonian pre-Permian rocks, and the Permian system, including post-Carboniferous pre-Triassic rocks, are established by long world-wide usage and are acceptable, desirable divisions for the standard classification of the geologic column of North America.

(5) Many of the geologic systems that are accepted as standard, including Carboniferous and Permian, owe definition of their span to a variety of circumstances, which are unequal in significance and which are partly determined by the history of early stratigraphic work in Europe.

(6) The boundaries of systems are defined by disconformities or angular unconformities in many but not all instances in the type regions, and the boundaries may or may not be marked by unconformities in other regions. Important unconformities are found within the limits of some systems, both in the type regions and elsewhere.

(7) Revision of systemic boundaries has been made many times. Neither priority of definition nor established usage prevents such revision whenever good evidences for change are found, and acceptance of the revision depends largely on the validity of the evidences adduced. Conservatism and inertia retard acceptance of change.

(8) Precise definition of the Carboniferous-Permian boundary, in so far as the type regions of these systems are concerned, depends on study in eastern Russia, which offers a fairly complete section of fossiliferous marine rocks of Upper Carboniferous and Lower Permian age, rather than in the British Isles, where corresponding beds are less complete and largely non-marine.

(9) In the Russian section, the Carboniferous-Permian boundary has been drawn uniformly for many years at the base of the Artinskian series, which overlies the "*Schwagerina* zone" at the top of the so-called Uralian series.

(10) Several Russian and American geologists have advocated revision of the Carboniferous-Permian boundary in the Russian section, transferring the "*Schwagerina* zone" (zone of *Pseudoschwagerina*), called the Sakmarian series in the southern Urals, into the Lower Permian.

(11) The Carboniferous-Permian boundary has been drawn at several different horizons in the conformable succession of beds comprising the Big Blue series in the northern Mid-Continent region of North America, the lowest suggested position being coincident with a disconformity that marks the base of this series. All of the positions for the boundary advocated, except that of Romer (1935), lie below part or all of the zone of *Pseudoschwagerina*.

(12) Similar variation in the placement of the Carboniferous-Permian boundary is found in north-central Texas. The line has been drawn in the mid-portion of the Cisco group, at the base or approximately 400 feet above the base of the Wichita group (revised), or at the top of the Wichita. All these positions, except the last, appear to lie below part or all of the zone of *Pseudoschwagerina*.

(13) The lower boundary of the Permian in the trans-Pecos Texas region has been placed by all writers, except Girty and Romer, at the base of the Wolfcamp beds, but before 1932, strata containing the *Uddenites* fauna, now known to belong in the lower Cisco (upper Pennsylvanian), were locally included in the Wolfcamp. Restricted to exclude the *Uddenites*-bearing beds, the Wolfcamp represents the zone of *Pseudoschwagerina*, which in this area is found to rest unconformably on beds ranging from upper Pennsylvanian to pre-Cambrian.

(14) Occurrence of typical Rotliegende (Autunian) plants in the Dunkard group of the northern Appalachian area has led, since 1880, to classifying all or part of these beds as Lower Permian.

(15) Plant remains similar or identical with those of the Dunkard and occurring in redbeds of western Europe that have been regarded universally as belonging to the Lower Permian, are found in beds of the *Pseudoschwagerina* zone in Kansas, Oklahoma, and Texas.

(16) Because the *Pseudoschwagerina* zone is identifiable in each of the important Permian basins of the world, except Australia, and in many places is found to occur next above an important hiatus, and because paleontologic ties with overlying beds appear as strong as

(and, according to some paleontologists, much stronger than) with underlying strata, arguments for classifying the Sakmarian, Wolfcamp, and equivalent rocks as Lower Permian appear to be well founded.

(17) Acceptance of a post-Sakmarian pre-Artinskian position of the Carboniferous-Permian boundary would not only require drastic revision in the classification of many American beds that have always been regarded as Permian, but it would equally necessitate transfer of Rotliegende and other Autunian beds of western Europe from Lower Permian into the Carboniferous.

(18) The course that involves least confusion and that seems best to accord with paleontologic and stratigraphic evidences from all parts of the world, is to accept the revision of the Carboniferous-Permian boundary in the type section of eastern Russia, as advocated by Ružencev, Nalivkin, Dunbar, Miller, and others.

There may be some who think that the Carboniferous-Permian boundary should stand rigidly fixed at the base of the Artinskian, or even higher, at the base of the Kungurian, where Murchison originally placed this line. Those who take this view will tell us to change the position of the Carboniferous-Permian boundary in American sections, even though they appreciate the revolution in ideas that is involved in transferring many rock formations and many familiar "Permian" guide fossils to a place in the Carboniferous.

There may be some who choose to use noncommittal designations, such as "Carboniferous or Permian," "Carboniferous?", or "Permian?" for beds of the *Pseudoschwagerina* zone, electing a fence-top seat until such time as an accumulating mass verdict sways judgment. With these we can not quarrel, for it must be said that the Big Blue, Wichita, Wolfcamp, Dunkard, and various other beds that have been classed as Permian so commonly, appear to be incorrectly designated thus, unless pre-Artinskian beds are admitted to this system. It is proper to add that responsible organizations, such as national and state geological surveys, advisedly may choose to avoid commitments on questions of classification and nomenclature that are in flux.

American geologists will probably be disposed very generally and readily to accept revision of the Carboniferous-Permian boundary that defines the zone of *Pseudoschwagerina* as lowermost Permian. Such definition involves very little or no change in our previous classification. It seems wholly reasonable to conclude that geologists engaged in study of the Carboniferous and Permian rocks in North America, Asia, and other continents are concerned equally with their

European colleagues in questions of the definition of these systems, and with adequate knowledge of stratigraphic evidences, both those from the type sections and elsewhere, they are equally entitled to judgment.

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BIBLIOGRAPHY

ADAMS, G. I., *1903*, "Stratigraphic Relations of the Red Beds to the Carboniferous and Permian in Northern Texas," *Bull. Geol. Soc. America*, Vol. 14, pp. 191–200.

———, GIRTY, G. H., and WHITE, D., *1903*, "Stratigraphy and Paleontology of the Upper Carboniferous Rocks of the Kansas Section," *U. S. Geol. Survey Bull. 211*, pp. 1–123.

ADAMS, J. E., CHENEY, M. G., DEFORD, R. K., DICKEY, R. I., DUNBAR, C. O., HILLS, J. M., KING, R. E., LLOYD, E. R., MILLER, A. K., and NEEDHAM, C. E., *1939*, "Standard Permian Section of North America," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, pp. 1673–81.

AURIN, F. L., OFFICER, H. G., and GOULD, C. N., *1926*, "The Subdivision of the Enid Formation," *ibid.*, Vol. 10, pp. 786–99.

BAKER, A. A., and REESIDE, J. B., JR., *1929*, "Correlation of the Permian of Southern Utah, Northern Arizona, Northwestern New Mexico, and Southwestern Colorado," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, pp. 1413–48; 12 figs.

BAKER, C. L., and BOWMAN, W. F., *1917*, "Geologic Exploration of the Southeastern Front Range of Trans-Pecos Texas," *Univ. Texas Bull. 1753*, pp. 67–172.

BAKER, C. L., *1929*, "Depositional History of the Red Beds and Saline Residues of the Texas Permian," *Univ. Texas Bull. 2901*, pp. 9–72.

BASS, N. W., *1929*, "The Geology of Cowley County, Kansas," *Kansas Geol. Survey Bull. 12*, pp. 1–203.

———, *1936*, "Origin of the Shoestring Sands of Greenwood and Butler Counties, Kansas," *ibid., Bull. 23*, pp. 1–135.

BEEDE, J. W., *1900*, "A Reconnaissance of the Blue Valley Permian," *Kansas Univ. Quart.*, Vol. 9, pp. 19–202.

BEEDE, J. W., and SELLARDS, E. H., *1905*, "Stratigraphy of the Eastern Outcrop of the Kansas Permian," *Amer. Geologist*, Vol. 36, pp. 83–111.

BEEDE, J. W., and ROGERS, A. F., *1908*, "Coal Measures Faunal Studies: Faunal Divisions of the Kansas Coal Measures," *Kansas Univ. Geol. Survey*, Vol. 9, pp. 318–85.

BEEDE, J. W., *1909*, "The Bearing of the Stratigraphic History and Invertebrate Fossils on the Age of the Anthrocolithic Rocks of Kansas and Oklahoma," *Jour. Geology*, Vol. 17, pp. 710–29.

———, *1914*, "The Neva Limestone in Northern Oklahoma, with Remarks upon the Correlation of the Vertebrate Fossil Beds of the State," *Oklahoma Geol. Survey Bull. 21*, pp. 1–37.

———, *1914a*, "Eastern Outcrop of the Permian Red Beds in Oklahoma, with a Discussion of Lithologic and Color Changes," *ibid.*, pp. 21–37.

———, *1918*, "Notes on the Geology and Oil Possibilities of the Northern Diablo Plateau in Texas," *Univ. Texas Bull. 1852*, pp. 1–40.

———, *1922*, "Age and Development of the Red Beds and Terrestrial Vertebrates of the Appalachian and Kansas-Texas Regions," *Bull. Geol. Soc. America*, Vol. 33, pp. 671–88.

———, and KNIKER, H. T., *1924*, "Species of the Genus *Schwagerina* and Their Stratigraphic Significance," *Univ. Texas Bull. 2433*, pp. 1–78.

BERTRAND, P., *1937*, "Discussion of Paper by Emily Dix" (see E. Dix, p. 179, 1937).

BLANCHARD, W. GRANT, and DAVIS, MORGAN J., *1929*, "Permian Stratigraphy and Structure of Parts of Southeastern New Mexico and Southwestern Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, pp. 957–95.

BÖSE, E., *1917*, "The Permo-Carboniferous Ammonoids of the Glass Mountains, West Texas, and Their Stratigraphical Significance," *Univ. Texas Bull. 1762*, pp. 1–241.

———, *1928*, "On Ammonoids from the Abo Sandstone of New Mexico and the Age of the Beds Which Contain Them," *Amer. Jour. Sci.*, Ser. 4, Vol. 49, pp. 51–60.

BRADY, F. H., *1931*, "Minnelusa Formation of Beulah District, Northwestern Black Hills, Wyoming," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15, pp. 183–88.

BRANSON, C. C., *1936*, "Carboniferous Stratigraphy of Wyoming," *Proc. Geol. Soc. America* (1935), p. 392.

———, *1939*, "Pennsylvanian Formations of Central Wyoming," *Bull. Geol. Soc. America*, Vol. 50, pp. 1199–1226.

BRANSON, E. B., *1916*, "The Lower Embar of Wyoming and Its Fauna," *Jour. Geology*, Vol. 24, pp. 639–65.

BUBNOFF, SERGE VON, *1926–1936*, *Geologie von Europa*, 4 vols., pp. 1–1607. Borntraeger, Berlin.

CANNON, R. L., and CANNON, JOE, *1932*, "Structural and Stratigraphic Development of South Permian Basin, West Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16, pp. 189–204.

CASE, E. C., *1915*, "The Permo-Carboniferous Red Beds of North America and Their Vertebrate Fauna," *Carnegie Inst. Washington Pub. 207*, pp. 1–176.

———, *1919*, "The Environment of Life in the Late Paleozoic in North America; a Paleogeographic Study," *ibid., Pub. 283*, pp. 1–273, Figs. 1–7, paleogeographic map.

———, *1922*, "Study of the Vertebrate Fauna and Paleogeography of North America in the Permian Period, with Especial Reference to World Relations," *ibid., Year Book 20*, pp. 443–45.

———, *1924*, "Study of the Vertebrate Fauna and Paleogeography of North America in the Permian Period, with Especial Reference to World Relations," *ibid., Year Book 22*, p. 349.

CHAMBERLIN, R. T., *1935*, "Certain Aspects of Geologic Classifications and Correlations," *Science*, New Ser., Vol. 81, pp. 183–90, and 216–18.

CHAMBERLIN, T. C., and SALISBURY, R. D., *1906*, *Geology*, 3 vols.; Vol. II, *Earth History*, pp. 1–692. Holt, New York.

CHENEY, M. G., *1940*, "Geology of North-Central Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 1 (January).

CLARK, G. C., and COOPER, C. L., *1930*, "Oil and Gas in Oklahoma; Kay, Grant, Garfield, and Noble Counties," *Oklahoma Geol. Survey Bull. 40*, Vol. 2, pp. 67–104. (Issued as *Bull. 40-H*, March, 1927.)

CONDRA, G. E., and BENGSTON, N. A., *1915*, Pennsylvanian Formations of Southeastern Nebraska," *Nebraska Acad. Sci. Pub. 9*, No. 2, pp. 1–60.

CONDRA, G. E., *1927*, "The Stratigraphy of the Pennsylvanian System in Nebraska," *Nebraska Geol. Survey*, Second Ser., Bull. 1, pp. 1–291.

———, DUNBAR, C. O., and MOORE, R. C., *1930*, "Persistence of Thin Beds in the Pennsylvanian of the Northern Mid-Continent Region" (abstract), *Bull. Geol. Soc. America*, Vol. 53, p. 140.

———, SCHRAMM, E. F., and LUGN, A. L., *1931*, "Deep Wells of Nebraska," *Nebraska Geol. Survey*, Second Ser., Bull. 4, pp. 1–288.

———, and UPP, J. E., *1931*, "Correlation of the Big Blue Series in Nebraska, "*ibid.*, Bull. 6, pp. 1–74.

CONDRA, G. E., *1935*, "Geologic Cross-Section, Forest City, Missouri, to DuBois, Nebraska," *ibid.*, Paper 8, pp. 1–23.

CONDRA, G. E., and REED, E. C., *1935*, "Permo-Pennsylvanian Section of the Hartville Area of Wyoming," *ibid.*, Paper 9, pp. 1–46.

CONYBEARE, W. D., and PHILLIPS, W., *1822*, *Outlines of the Geology of England and Wales*, pp. 278, 320–64.

CRAGIN, F. W., *1896*, "The Permian System in Kansas," *Colorado College Studies*, Vol. 6, pp. 1–48.
CROOKALL, R., *1932*, "The Stratigraphical Distribution of British Lower Carboniferous Plants," *Summ. Progress, Geol. Survey Great Britain*, p. 69.
CUMMINS, W. F., *1890*, "The Permian of Texas and Its Overlying Beds," *Texas Geol. Survey First Ann. Rept.*, pp. 183–97.
———, *1891*, "Report on the Geology of Northwestern Texas," *ibid.*, *Second Ann. Rept.*, pp. 357–552.
———, *1897*, "Texas Permian," *Trans. Texas Acad. Science*, Vol. 2, pp. 93–98.
———, *1908*, "The Localities and Horizons of Permian Vertebrate Fossils in Texas," *Jour. Geology*, Vol. 16, pp. 737–45.
DARRAH, W. C., *1934*, "Stephanian in America," *Geol. Soc. America Proc. 1933*, p. 451.
———, *1937*, "American Carboniferous Floras," *Deuxième Congrès de Stratigraphie Carbonifère, 1935 Heerlen, Comptes Rendus*, Vol. 1, pp. 109–29.
DARTON, N. H., *1899*, "Geology and Water Resources of Nebraska West of the 103d Meridian," *U. S. Geol. Survey Ann. Rept. 19*, Pt. 4, pp. 719–85.
———, *1915*, "Guidebook of the Western United States, Part C, The Santa Fe Route," *U. S. Geol. Survey Bull. 613*, pp. 1–194.
———, *1925*, "A Resumé of Arizona Geology," *Univ. Arizona Bull. 119*, Geol. Ser., No. 3, pp. 1–298.
———, *1926*, "The Permian of Arizona and New Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, pp. 819–52.
———, *1928*, " 'Red Beds' and Associated Formations in New Mexico," *U. S. Geol. Survey Bull. 794*, pp. 1–356.
———, and KING, P. B., *1932*, "Western Texas and Carlsbad Caverns," *Intern. Geol. Congress, 16th Session, U. S. A.*, Guidebook 13, Excursion C-1, pp. 1–38.
DIX, EMILY, *1937*, "The Succession of Fossil Plants in the South Wales Coalfield, with Special Reference to the Existence of the Stephanian," *Deuxième Congrès de Stratigraphie Carbonifère, 1935 Heerlen, Comptes Rendus*, Vol. 1, pp. 159–79.
DOTT, R. H., *1928*, "Notes on Pennsylvanian Paleogeography, with Special Reference to South-Central Oklahoma," *Oklahoma Geol. Survey Bull. 40*, Vol. 1, pp. 51–69. (Issued as *Bull. 40-J*, March, 1927.)
———, *1930*, "Oil and Gas in Oklahoma: Garvin County," *ibid.*, *Bull. 40*, Vol. 2, pp. 119–43. (Issued as *Bull. 40-K*, May, 1927.)
———, *1932*, "Lower Permian Correlations in Cleveland, McClain, and Garvin Counties, Oklahoma (with Discussion by Sherwood Buckstaff)," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16, pp. 119–34.
DILLÉ, G. S., *1930*, "Minnelusa of Black Hills of South Dakota," *ibid.*, Vol. 14, pp. 619–23.
DRAKE, N. F., *1893*, "Report on the Colorado Coalfield of Texas," *Texas Geol. Survey Ann. Rept. 4*, Pt. 1, pp. 355–446.
DUMBLE, E. T., *1890*, "Report of the State Geologist for 1889," *ibid.*, *Ann. Rept. 1*, pp. 17–109.
DUNBAR, C. O., and CONDRA, G. E., *1927*, "The Fusulinidae of the Pennsylvanian System in Nebraska," *Nebraska Geol. Survey Bull. 2*, 2d Ser., pp. 1–135, Pls. 1–15, Figs. 1–13.
———, and CONDRA, G. E., *1932*, "Brachiopoda of the Pennsylvanian System in Nebraska," *ibid.*, *Bull. 5*, pp. 1–357.
———, and SKINNER, J. W., *1936*, "*Schwagerina* versus *Pseudoschwagerina* and *Paraschwagerina*," *Jour. Paleontology*, Vol. 10, pp. 83–91, 2 pls.
———, and SKINNER, J. W., *1937*, "Permian Fusulinidae of Texas," *Univ. Texas Bull. 3701*, pp. 517–825.
DUNBAR, C. O., *1940*, "The Type Permian: Its Classification and Correlation," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, February, pp. 237–81.
EDMUNDS, F. H., and OAKLEY, K. P., *1936*, "British Regional Geology, The Central England District," *Great Britain Geol. Survey and Museum* (London), pp. 1–88.
ELIAS, M. K., *1935*, "Correlation of Upper Carboniferous and Artinskian in Russia with American Late Paleozoic Rocks," *Geol. Soc. America, Proc. 1934*, p. 370.
———, *1936*, "Late Paleozoic Plants of the Midcontinent Region as Indicators of Time and Environment," *Intern. Geol. Congress, Rept. 16th Session, U. S. A.*, Vol. 1, pp. 691–700.
———, *1937*, "Elements of the Stephanian Flora in the Midcontinent of North America," *Deuxième Congrès de Stratigraphie Carbonifère, Heerlen, 1935, Comptes Rendus*, Vol. 1, pp. 203–12.

———, *1937a*, "Carboniferous and Permian of the Southern Urals," *Amer. Jour. Sci.*, 5th Ser., Vol. 33, pp. 279–95.
———, *1938*, "*Properrinites plummeri* Elias, N. Gen. and Sp., from Late Paleozoic Rocks of Kansas," *Jour. Paleontology*, Vol. 12, pp. 101–05.
ELLEDGE, E. R., *1921*, "The Economic Geology of the Arkansas City District," *Kansas Geol. Survey Bull. 8*, pp. 1–37.
FATH, A. E., *1921*, "Geology of the Eldorado Oil and Gas Field, Butler County, Kansas," *ibid.*, *Bull. 7*, pp. 1–187.
FONTAINE, W. M., and WHITE, I. C., *1880*, "The Permian or Upper Carboniferous Flora of West Virginia and Southwestern Pennsylvania," *Pennsylvania Geol. Survey*, 2d Ser., Prof. Paper 9, pp. 1–143.
FRECH, FRITZ, *1899*, *Lethaea Paleozoica*, Band 2, Lief. 2, p. 378.
———, *1901*, *Lethaea Paleozoica*, Band 2, Lief. 3, p. 514.
FREDERIKS, G., *1934*, "Uralian and Permian of the Urals," *Bull. Geol. Soc. China*, Vol. 13, pp. 505–61.
———, and EMELYANTZEV, T., *1934*, "Ueber das Alter der *Cora- und Omphalotrochus*-Schichten des 'Oberkarbons' am Ural," *Centr. Miner.*, Abt. 13, pp. 15–18.
GEINITZ, H. B., *1866*, "Carbonformation und Dyas in Nebraska," *Königl. Leopoldino-Carolinische Deutsche Akad. Naturf.*, Verhandl. 33, Abh. 4, pp. 1–91.
GIRTY, G. H., *1908*, "The Guadalupian Fauna," *U. S. Geol. Survey Prof. Paper 58*, pp. 1–651.
———, *1910*, "The Fauna of the Phosphate Beds of the Park City Formation in Idaho, Wyoming, and Utah," *ibid.*, *Bull. 436*, pp. 1–82.
———, *1911*, "Discussion" (of C. H. Gordon's paper): see under GORDON.
GORDON, C. H., *1911*, "The Wichita Formation of Northern Texas, with Discussion of the Fauna and Flora by George H. Girty and David White," *Jour. Geology*, Vol. 19, pp. 110–34.
———, *1913*, "Geology and Underground Waters of the Wichita Region, North-Central Texas," *U. S. Geol. Survey Water-Supply Paper 317*, pp. 1–88.
GOTHAN, W., *1937*, "Die Frage des synchronismus der Perm- und Stephan-Floren und ihre Charakteristiks," *Deuxième Congrès de Stratigraphie Carbonifère, Heerlen, 1935, Comptes Rendus*, Vol. 1, pp. 213–17.
GOUIN, FRANK, *1930*, "Oil and Gas in Oklahoma; Stephens County," *Oklahoma Geol. Survey Bull. 40*, Vol. 2, pp. 21–66. (Issued as *Bull. 40-E*, October, 1926.)
———, *1930a*, "Oil and Gas in Oklahoma; Beckham County," *ibid.*, pp. 165–77. (Issued as *Bull. 40-M*, May, 1927.)
GOULD, C. N., OHERN, D. W., and HUTCHISON, L. L., *1910*, "Proposed Groups of Pennsylvanian Rocks of Eastern Oklahoma," *Univ. Oklahoma Research Bull. 3*, pp. 1–15.
GOULD, C. N. *1925*, "Index to the Stratigraphy of Oklahoma," *Oklahoma Geol. Survey Bull. 35*, pp. 1–115.
———, *1926*, "The Correlation of the Permian of Kansas, Oklahoma, and Northern Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, pp. 144–53.
———, *1927*, "The Upper Paleozoic Rocks of Oklahoma; Stratigraphy and Areal Geology," *Oklahoma Geol. Survey Bull. 41*, pp. 5–21.
———, and WILLIS, ROBIN, *1927*, "Tentative Correlation of the Permian Formations of the Southern Great Plains," *Geol. Soc. America Bull.*, *38*, pp. 431–42.
GRABAU, A., *1931*, "The Permian of Mongolia," *Natural History of Asia*, Vol. 4 (Amer. Mus. Nat. Hist.), pp. 1–665.
HAWORTH, E., *1898*, "Stratigraphy of the Kansas Coal Measures," *Kansas Univ. Geol. Survey*, Vol. 3, pp. 10–105.
———, and BENNETT, J., *1908*, "General Stratigraphy (Kansas)," *ibid.*, Vol. 9, pp. 57–121.
HAY, ROBERT, *1893*, "Geology and Mineral Resources of Kansas," *Kansas State Board of Agriculture Biennial Rept.*, Pt. 2, pp. 99–162.
———, *1893a*, "President's Address (The Geology of the Great Plains)," *Kansas Acad. Sci.*, Vol. 13, pp. 3–6.
HAYASAKA, ICHIRO, *1936*, "The Japanese Carboniferous," *Intern. Geol. Congress, Rept. 16th Session, U. S. A.*, Vol. 1, pp. 585–92.
HAYDEN, F. V., *1858*, "Explanations of a Second Edition of a Geological Map of Nebraska and Kansas, Based on Information Obtained in an Expedition to the Black Hills," *Proc. Philadelphia Acad. Nat. Sci.*, pp. 139–58.
———, *1872*, "Final Report of the United States Geological Survey of Nebraska and

Portions of the Adjacent Territories," *U. S. 42d Congress, 1st. Sess., House Ex. Doc. 19*, pp. 1–82.

HENBEST, LLOYD G., *1938*, "Notes on the Ranges of Fusulinidae in the Cisco Group (Restricted) of the Brazos River Region, North-Central Texas," *Univ. Texas Bull. 3801*, pp. 237–44.

HUBBARD, W. E., and THOMPSON, W. C., *1926*, "The Geology and Oil Fields of Archer County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 10, pp. 457–81.

JOHNSON, MEREDITH E., *1929*, "Topographic and Geologic Atlas of Pennsylvania, No. 27, Pittsburgh Quadrangle; Geology and Mineral Resources," *Pennsylvania Geol. Survey*, 4th Ser., pp. 1–236.

KARPINSKY, A., *1889*, "Ueber die Ammoneen der Artinsk-Stufe," *Mem. St. Petersbourg Acad. Sci.*, 7th Ser., Vol. 37, No. 2, pp. 1–114, Pls. 1–5, Figs. 1–32.

KELLETT, BETTY, *1932*, "Geologic Cross Section from Western Missouri to Western Kansas Showing Detailed Correlation of Permian Big Blue Series and Pennsylvanian" (with Classification of the Lower Permian and Pennsylvanian Systems of Kansas and Nebraska, 2d ed., by R. C. Moore and G. E. Condra), *Kansas Geol. Soc.* (October, 1932).

KEYTE, I. A., BLANCHARD, W. G., and BALDWIN, H. L., *1927*, "Gaptank-Wolfcamp Problem of the Glass Mountains, Texas," *Jour. Paleontology*, Vol. 1, pp. 175–78.

———, *1929*, "Correlation of Pennsylvanian-Permian of Glass Mountains and Delaware Mountains," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, pp. 903–06.

KING, P. B., and KING, R. E., *1928*, "The Pennsylvanian and Permian Stratigraphy of the Glass Mountains," *Univ. Texas Bull. 2801*, pp. 109–45.

———, and KING, R. E., *1929*, "Stratigraphy of Outcropping Carboniferous and Permian Rocks of Trans-Pecos Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, pp. 907–26.

———, *1931*, "The Geology of the Glass Mountains, Texas; Part 1, Descriptive Geology," *Univ. Texas Bull. 3038*, pp. 1–137.

———, *1934*, "Permian Stratigraphy of Trans-Pecos Texas," *Bull. Geol. Soc. America*, Vol. 45, pp. 697–98.

———, *1936*, "Unconformities in the Later Paleozoic of Trans-Pecos Texas," *Univ. Texas Bull. 3501*, pp. 131–35.

KING, R. E., *1929*, "Correlation of the Permian of Trans-Pecos Texas, *Pan-Amer. Geol.*, Vol. 51, pp. 230–31.

———, *1931*, "The Geology of the Glass Mountains, Texas: Part II, Faunal Summary and Correlation of the Permian Formations, with Description of Brachiopoda," *Univ. Texas Bull. 3042*, pp. 1–245.

LAPWORTH, C., *1879*, *Geol. Mag.* (London), N. S., Vol. 6, pp. 12–14.

LEE, WALLACE, *1938*, "Stratigraphy of the Cisco Group of the Brazos Basin," *Univ. Texas Bull. 3801*, pp. 11–88.

LEIGHTON, HENRY, *1926*, "The Geology of Pittsburgh and Its Environs; a Popular Account of the General Geologic Features of the Region," *Annals Carnegie Mus.*, Vol. 17, pp. 91–162.

LICHAREV, BORIS K., *1934*, "The Upper Carboniferous of Fergana and the Question of the Boundary between the Carboniferous and the Permian," *Bull. Geol. Soc. China*, Vol. 13, pp. 155–82.

———, *1934a*, "The Permian System; on the Question of Its Extent and Stratigraphy," *Problems Soviet Geology*, Vol. 1, pp. 161–75 (Russian; English summary, pp. 174–75).

LLOYD, A. M., and THOMPSON, W. C., *1929*, "Correlation of Permian Outcrops on Eastern Side of the West Texas Basin," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, pp. 945–56.

LONGWELL, C. R., *1928*, "Geology of the Muddy Mountains, Nevada," *U. S. Geol. Survey Bull. 798*, pp. 1–152.

———, and DUNBAR, C. O., *1936*, "Problems of Pennsylvanian-Permian Boundary in Southern Nevada," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20, pp. 1198–1207.

MANSFIELD, G. R., *1927*, "Geography, Geology and Mineral Resources of Part of Southeastern Idaho," *U. S. Geol. Survey Prof. Paper 152*, pp. 1–453.

MARCOU, J., *1864*, "Une Reconnaissance Géologique au Nebraska," *Bull. Soc. Géol. France*, Ser. 2, Vol. 21, pp. 132–46.

———, *1868*, "On the Dyas in Nebraska," *Trans. St. Louis Acad. Sci.*, Vol. 2, pp. 562–64.

———, *1892*, "On the Classification of the Dyas, Trias, and Jura in Northwest Texas," *Amer. Geologist*, Vol. 10, pp. 369–77.

McKee, E. D., *1938*, "The Environment and History of the Toroweap and Kaibab Formations of Northern Arizona and Southern Utah," *Carnegie Inst. Washington Pub. 492*, pp. 1–268, Pls. 1–48.
Meek, F. B., and Hayden, F. V., *1858*, "On the Probable Existence of Permian Rocks in Kansas Territory," *Proc. Philadelphia Acad. Nat. Sci.*, pp. 9–10.
———, and Hayden, F. V., *1859*, "Geological Explorations in Kansas Territory," *ibid.*, pp. 8–30; (in part), *Amer. Jour. Sci.*, Ser. 2, Vol. 27, pp. 424–32.
Meek, F. B., *1872*, "Report on the Paleontology of Eastern Nebraska with Some Remarks on the Carboniferous Rocks of That District," in Hayden, F. V., "Final Report on the Geological Survey of Nebraska," *U. S. 42d Congress, 1st Sess., House Ex. Doc. 19*, pp. 83–239.
Merrill, G. P., *1906*, "Contributions to the History of American Geology," *U. S. Nat. Mus. Rept. 1904*, pp. 189–733.
Miller, A. K., *1932*, "A Pennsylvanian Cephalopod Fauna from South-Central New Mexico," *Jour. Paleontology*, Vol. 6, pp. 11–60.
———, and Cline, L. M., *1934*, "The Cephalopods of the Phosphoria Formation of Northwestern United States," *ibid.*, Vol. 8, pp. 281–302.
Miller, A. K., *1936*, "A Species of the Ammonoid Genus *Artinskia* from the Lower Permian of Kansas," *ibid.*, Vol. 10, pp. 490–96.
———, *1937*, Discussion of M. K. Elias' "Carboniferous and Permian of the Southern Urals," *Amer. Jour. Sci.*, Ser. 5, Vol. 33, pp. 471–72.
———, *1938*, "Comparison of Permian Ammonoid Zones of Soviet Russia with Those of North America," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22, pp. 1014–19.
Moore, R. C., and Haynes, W. P., *1917*, "Oil and Gas Resources of Kansas," *Kansas Geol. Survey Bull. 3*, pp. 1–391.
Moore, R. C., *1918*, "The Environment of Camp Funston," *Kansas Geol. Survey Bull. 4*, pp. 1–81.
———, *1920*, "Oil and Gas Resources of Kansas; Part 2, Geology of Kansas," *ibid., Bull. 6*, Pt. 2, pp. 1–98.
———, and Plummer, F. B., *1922*, "Pennsylvanian Stratigraphy of North-Central Texas," *Jour. Geology*, Vol. 30, pp. 18–42.
———, and Landes, K. K., *1927*, "Underground Resources of Kansas," *Kansas Geol. Survey Bull. 13*, pp. 1–154.
Moore, R. C., *1929*, "Correlation of Pennsylvanian Formations of Texas and Oklahoma," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, pp. 883–901.
———, *1932*, "Pennsylvanian of the Northern Midcontinent Region," *Intern. Geol. Congress, 16th Session, U. S. A.*, Guidebook 20, Excursion C-2, pp. 1–8.
———, *1932a*, "A Reclassification of the Pennsylvanian System in the Northern Midcontinent Region," *Kansas Geol. Soc. Guidebook 6th Ann. Field Conference*, pp. 79–98.
———, *1933*, *Historical Geology*, pp. 1–673. McGraw-Hill Book Company, New York.
———, *1933a*, "Rock Formations of Kansas," *Kansas Geol. Soc. Stratigraphic Chart.*
———, and Moss, R. G., *1934*, "Pennsylvanian-Permian Boundary in the Northern Mid-Continent Area," *Geol. Soc. America, Proc., 1933*, p. 100.
Moore, R. C., *1935*, "Late Paleozoic Crustal Movements of Europe and North America" (with discussion), *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, pp. 1253–1307.
———, *1936*, "Pennsylvanian and Lower 'Permian' Rocks of the Kansas-Missouri Region," *Kansas Geol. Soc. Guidebook 10th Ann. Field Conference*, pp. 7–73.
———, *1936a*, "Stratigraphic Classification of the Pennsylvanian Rocks of Kansas," *Kansas Geol. Survey Bull. 22*, pp. 1–256.
———, *1936b*, " 'Carboniferous' Rocks of North America," *Intern. Geol. Congress, Rept. 16th Session, U. S. A.*, Vol. 1, pp. 593–616.
———, Elias, M. K., and Newell, N. D., *1936*, "A 'Permian' Flora from the Pennsylvanian Rocks of Kansas," *Jour. Geology*, Vol. 44, pp. 1–31.
Moore, R. C., *1937*, "Correlation of the Big Blue Series in Kansas and Northern Oklahoma," *Kansas Geol. Soc. Guidebook 11th Ann. Field Conference*, p. 84.
———, *1937a*, "Upper Carboniferous Rocks of Southeastern Kansas and Northeastern Oklahoma," *ibid.*, pp. 9–15.
———, and Landes, K. K., *1937*, *Geologic Map of Kansas*, 1: 500,000.
Mudge, B. F., *1866*, *First Annual Report on the Geology of Kansas*, pp. 1–56. Lawrence.
Murchison, R. I., *1835*, "Silurian System," *London and Edinburgh Philos. Mag. and Jour. Sci.* (3), Vol. 7, pp. 46–52.
———, *1841*, *Philos. Mag.* (3), Vol. 19, p. 419.

NEEDHAM, C. E., *1937*, "Some New Mexico Fusulinidae," *New Mexico School Mines Bull. 14*, pp. 1–88, Pls. 1–12.
NEWELL, N. D., *1937*, "Composite Section of Pennsylvanian and Lower Permian Rocks in Township 20 North, Oklahoma," *Kansas Geol. Soc. Guidebook 11th Ann. Field Conference*, p. 16.
———, *1937a*, "Late Paleozoic Pelecypods: Pectinacea," *Kansas Geol. Survey*, Vol. 10, pp. 1–123.
NICKELL, C. O., *1938*, "Stratigraphy of the Canyon and Cisco Groups on Colorado River in Brown and Coleman Counties, Texas," *Univ. Texas Bull. 3801*, pp. 91–138.
PAECKELMANN, W., and SCHINDEWOLF, O. H., *1937*, "Die Devon-Karbon-Grenze," *Deuxième Congrès de Stratigraphie Carbonifère, Heerlen, 1935, Comptes Rendus*, Vol. 2, pp. 703–14.
PLUMMER, F. B., *1919*, "Preliminary Paper on the Stratigraphy of the Pennsylvanian Formations of North-Central Texas," *Bull. Amer. Assoc. Petrol. Geol*, Vol. 3, pp. 132–50.
———, and MOORE, R. C., *1921*, "Stratigraphy of the Pennsylvanian Formations of North-Central Texas," *Univ. Texas Bull. 2132*, pp. 1–237.
PLUMMER, F. B., and SCOTT, GAYLE, *1937*, "Upper Paleozoic Ammonites in Texas," *Univ. Texas Bull. 3701*, pp. 13–516.
POWERS, SIDNEY, *1928*, "Age of the Folding of the Oklahoma Mountains—the Ouachita, Arbuckle, and Wichita Mountains of Oklahoma and the Llano-Burnet and Marathon Uplifts of Texas," *Bull. Geol. Soc. America*, Vol. 39, pp. 1331–72.
PROSSER, C. S., *1894*, "Kansas River Section of the Permo-Carboniferous and Permian Rocks of Kansas," *ibid.*, Vol. 6, pp. 29–54.
———, *1895*, "The Classification of the Upper Paleozoic Rocks of Central Kansas," *Jour. Geology*, Vol. 3, pp. 682–705, 764–800.
———, *1897*, "The Permian and Upper Carboniferous of Southern Kansas," *Kansas Univ. Quart.*, Vol. 6, pp. 149–75.
———, *1897a*, "Comparison of the Carboniferous and Permian Formations of Nebraska and Kansas," *Jour. Geology*, Vol. 5, pp. 1–16, 148–72.
———, *1899*, "Correlation of the Carboniferous Rocks of Nebraska with Those of Kansas," *ibid.*, Vol. 7, pp. 342–56.
———, *1902*, "Revised Classification of the Upper Paleozoic Formations of Kansas," *ibid.*, Vol. 10, pp. 703–37.
———, and BEEDE, J. W., *1904*, "Description of the Cottonwood Falls Quadrangle, Kansas," *U. S. Geol. Survey Geol. Atlas, Cottonwood Falls Folio 109*, pp. 1–6.
PROSSER, C. S., *1905*, "Notes on the Permian Formations of Kansas," *Amer. Geologist*, Vol. 36, pp. 142–61.
———, *1910*, "The Anthracolithic or Upper Paleozoic Rocks of Kansas and Related Regions," *Jour. Geology*, Vol. 18, pp. 125–61.
RANSOME, F. L., *1916*, "Some Paleozoic Sections in Arizona and Their Correlation," *U. S. Geol. Survey Prof. Paper 98*, pp. 133–66.
REICHARDT, W., *1936*, "Zur Frage der Karbon-Perm Grenze (abs.)," *Zeits. Deutsch. Geol. Ges.*, Bd. 88, H.g., pp. 583–84.
ROMER, A. S., *1928*, "Vertebrate Faunal Horizons in the Texas Permo-Carboniferous Red Beds," *Univ. Texas Bull. 2801*, pp. 67–108.
———, *1935*, "Early History of Texas Red-Beds Vertebrates," *Bull. Geol. Soc. America*, Vol. 46, pp. 1597–1658.
ROTH, R., *1931*, "New Information on the Base of the Permian in North-Central Texas," *Jour. Paleontology*, Vol. 5, pp. 295.
RUŽENCEV, V. E., *1936*, "New Data on the Stratigraphy of the Carboniferous and Lower Permian of the Orenburg and Aktiubinsk Districts (Russia)," *Problems Soviet Geol.*, Vol. 6, pp. 470–506 (Russian; English summary, pp. 505–06).
———, *1936a*, "Paleontological Notes on the Carboniferous and Permian Ammonoids," *ibid.*, pp. 1072–88 (Russian; English summary, pp. 1086–88).
———, *1936b*, "Contributions to the Stratigraphy of the Upper Paleozoic of the Aktiubinsk and Orenburg Districts," *ibid.*, pp. 49–56 (Russian).
———, *1937*, "Stratigraphical Outline of the Upper Carboniferous and Lower Permian Deposits in the Orenburg District," *Bull. Moscow Soc. Nat.*, N. S., Vol. 45, Sec. Geol., Vol. 15(3), pp. 187–214.
SCHINDEWOLF, O. H., *1928*, "Die Liegendgrenze des Karbons im Lichte biostratigraphischer Kritik," *Congrès pour l'Avancement des Études de Stratigraphie Carbonifère, Heerlen, 1927, Comptes Rendus*, pp. 651–59.

SCHUCHERT, C., *1906*, "The Russian Carboniferous and Permian Compared with Those of India and America," *Amer. Jour. Sci.*, Ser. 4, Vol. 22, pp. 29–46, 143–58.
———, *1910*, "Paleogeography of North America," *Bull. Geol. Soc. America*, Vol. 20, pp. 427–606.
———, *1914*, "The Delimitation of the Geologic Periods Illustrated by the Paleogeography of North America," *Intern. Geol. Congress, 12th Session, Comptes Rendus*, pp. 555–91.
———, *1924*, "The Paleogeography of Permian Time in Relation to the Geography of Earlier and Later Periods," *Proc. Pan-Pacific Sci. Cong. Australia 1923*, Vol. 2, pp. 1079–91.
———, *1927*, "The Pennsylvanian-Permian Systems of Western Texas," *Amer. Jour. Sci.*, Ser. 5, Vol. 14, pp. 381–401.
———, *1928*, "Review of Late Paleozoic Formations and Faunas, with Special Reference to the Ice Age of Middle Permian Time, *Bull. Geol. Soc. America*, Vol. 39, pp. 769–886.
———, *1935*, "Correlation of More Important Marine Permian Sequences," *Bull. Geol. Soc. America*, Vol. 46, pp. 1–46.
SCOTT, GAYLE, and PLUMMER, F. B., *1931*, "Evolution of the Family Prolecanitidae in the North Texas Pennsylvanian," *ibid.*, Vol. 42, pp. 355–56.
SEDGWICK, A., *1835* (The Cumbrian [Cambrian] groups), abs., *Edinburgh New Philos. Jour.*, Vol. 19, p. 390.
———, and MURCHISON, R. I., *1839*, "Devonian System (abs.)," *Proc. Geol. Soc. London*, Vol. 3, No. 63, pp. 121–23.
SELLARDS, E. H., *1909*, "Fossil Plants of the Upper Paleozoic of Kansas," *Kansas Univ. Geol. Survey*, Vol. 9, pp. 386–480.
———, *1932*, "The Pre-Paleozoic and Paleozoic Systems in Texas," *Univ. Texas Bull. 3232*, p. 140.
———, *1936*, "Structural Map of Texas," *Univ. Texas Bur. Econ. Geology.*
SHANNON, C. W., and TROUT, L. E., *1915*, "Petroleum and Natural Gas in Oklahoma: Pt. 1, General Information Concerning Oil and Gas: Geology of Oklahoma," *Oklahoma Geol. Survey Bull. 19*, pp. 1–133.
SHUMARD, B. F., *1858*, "Notice of New Fossils from the Permian Strata of New Mexico and Texas," *Trans. St. Louis Acad. Sci.*, Vol. 1, pp. 290–97.
SMITH, J. P., *1903*, "Carboniferous Ammonoids of America," *U. S. Geol. Survey Mon. 42*, pp. 1–211.
———, *1929*, "The Transitional Permian Ammonoid Fauna of Texas," *Amer. Jour. Sci.*, Ser. 5, Vol. 17, pp. 63–80.
STEVENSON, J. J., *1904–1907*, "Carboniferous of the Appalachian Basin," *Bull. Geol. Soc. America*, Vol. 15, pp. 37–210, Vol. 17, pp. 65–228; Vol. 18, pp. 29–178.
SWALLOW, G. C., *1858*, "On Permian Strata in Kansas Territory," *Amer. Jour. Sci.*, Ser. 2, Vol. 25, p. 305.
———, *1858a* (On Permian in Kansas), *Trans. St. Louis Acad. Sci.*, Vol. 1, p. 111.
———, and HAWN, F., *1858*, "The Rocks of Kansas," *ibid.*, pp. 173–97.
SWALLOW, G. C., *1859*, "The Rocks of Kansas," *Amer. Jour. Sci.*, Ser. 2, Vol. 26, pp. 182–88; *Proc. Amer. Assoc.*, Vol. 12, pp. 214–21.
———, *1866*, *Preliminary Report of the Geological Survey of Kansas*, pp. 1–198. Lawrence.
TSCHERNYSCHEW, T., *1902*, "Die Oberkarbonischen Brachiopoden des Ural und des Timan," *Comité Geol. (Russia) Mém.*, Vol. 16, pp. 1–749, Pls. 1–63.
THOMAS, H. D., *1934*, "Phosphoria and Dinwoody Tongues in Lower Chugwater of Central and Southeastern Wyoming," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 18, pp. 1655–97.
THOMPSON, M. L., *1936*, "Fusulinids from the Black Hills and Adjacent Areas in Wyoming," *Jour. Paleontology*, Vol. 10, pp. 95–113, Pls. 13–16.
TING, V. K., and GRABAU, A. W., *1936*, "The Permian of China and Its Bearing on Permian Classification," *Intern. Geol. Congress, Rept. 16th Session, U. S. A.*, pp. 663–76.
TRAVIS, A., *1930*, "Oil and Gas in Oklahoma: Oklahoma County," *Oklahoma Geol. Survey Bull. 40*, pp. 433–60. (Issued as *Bull. 40-SS*, May, 1930.)
UDDEN, J. A., BAKER, C. L., and BÖSE, E., *1916*, "Review of the Geology of Texas," *Univ. Texas Bull. 44*, pp. 1–164.
———, BAKER, C. L., and BÖSE, E., *1918*, "Notes on the Geology of the Glass Mountains," *ibid. Bull. 1753*, pp. 3–59.

UPSON, M. E., *1933*, "The Ostracoda of the Big Blue Series in Nebraska," *Nebraska Geol. Survey*, Ser. 2, Bull. 8, pp. 1–54.

VAN DER GRACHT, W. A. J. M. VAN WATERSCHOOT, *1932*, "Some Additional Notes on the Permo-Carboniferous Orogeny in North America," *Proc. K. Akad. Wetensch. Amsterdam*, Vol. 35, No. 9, pp. 1149–54.

VER WIEBE, WALTER A., *1932*, "Present Distribution and Thickness of Paleozoic Systems," *Bull. Geol. Soc. America*, Vol. 43, pp. 495–540.

WALKOM, A. B., *1936*, "The Limits of the Permian System in Australia," *Intern. Geol. Congress, Rept. 16th Session, U. S. A.*, Vol. 1, pp. 621–28.

WHEELER, H. E., *1934*, "The Carboniferous-Permian Dilemma," *Jour. Geology*, Vol. 42, pp. 62–70.

WHITE, C. A., *1889*, "On the Permian Formation of Texas," *Amer. Naturalist*, Vol. 23, pp. 109–28.

———, *1891*, "The Texas Permian and Its Mesozoic Types of Fossils," *U. S. Geol. Survey Bull. 77*, pp. 19–22.

WHITE, DAVID, *1903*, "Permian Elements in the Dunkard Flora," *Jour. Geology*, Vol. 11, pp. 105–06.

———, *1909*, "The Upper Paleozoic Floras, Their Succession and Range," *ibid.*, Vol. 17, pp. 320–41.

———, *1912*, "The Characters of the Fossil Plant *Gigantopteris* Schenck and Its Occurrence in North America," *Proc. U. S. Nat. Mus.*, Vol. 41, pp. 493–516.

———, *1924*, "Permian of Western America from the Paleobotanical Standpoint," *Proc. Pan-Pacific Sci. Congress, Australia, 1923*, Vol. 2, pp. 1050–77 (1926).

———, *1936*, "Some Features of the Early Permian Flora of America," *Intern. Geol. Congress, Rept. 16th Session, U. S. A.*, Vol. 1, pp. 679–89.

WHITE, MAYNARD P., *1932*, "Some Texas Fusulinidae," *Univ. Texas Bull. 3211*, pp. 1–105, Figs. 1–3, Pls. 1–10.

WILLIAMS, H. S., *1891*, "Correlation Papers: Devonian and Carboniferous," *U. S. Geol. Survey Bull. 80*, pp. 1–279.

WILLIAMS, J. S., in REESIDE, J. B., JR., *1932*, "Stratigraphic Nomenclature in the United States," *Intern. Geol. Congress, 16th Session, U. S. A.*, Guidebook 29.

WILLIAMS, J. S., *1938*, "Pre-Congress Permian Conference in the U. S. S. R.," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22, pp. 771–76.

———, *1939*, "Lower Permian of the Type Area, U. S. S. R.," *Jour. Washington Acad. Sci.*, Vol. 29.

WILLIS, ROBIN, *1929*, "Preliminary Correlation of the Texas and New Mexico Permian," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 13, pp. 997–1031.

WILMARTH, M. G., *1925*, "The Geologic Time Classification of the United States Geological Survey Compared with Other Classifications," *U. S. Geol. Survey Bull. 769*, pp. 1–138.

———, *1930*, "Tentative Correlation of the Named Geologic Units of Texas," *U. S. Geol. Survey Stratigraphic Chart* (September).

WRATHER, W. E., *1917*, "Notes on the Texas Permian," *Bull. Southwestern Assoc. Petrol. Geol.*, Vol. 1, pp. 93–106.

ZALESSKY, M. D., *1938*, "Sur une Division des Terrains Carbonifère et Permien du Bassin du Donetz d'apres leur Flore Fossile," *Deuxième Congrès de Stratigraphie Carbonifère, Heerlen, 1935, Comptes Rendus*, Vol. 3, pp. 1651–85.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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CLASSIFICATION OF PERMIAN ROCKS[1]

THE ASSOCIATION SUBCOMMITTEE ON THE PERMIAN

C. W. TOMLINSON, chairman, Ardmore, Oklahoma
RAYMOND C. MOORE, State geologist, Lawrence, Kansas
ROBERT H. DOTT, State geologist, Norman, Oklahoma
M. G. CHENEY, Coleman, Texas
JOHN EMERY ADAMS, Midland, Texas

PART I. PROBLEM AND CONCLUSIONS

FOREWORD

This subcommittee was appointed on May 9, 1939, by John G. Bartram as chairman of the Committee on Geologic Names and Correlations, with the approval of President Ley, pursuant to a resolution passed by that Committee at the March convention in Oklahoma City, "To prepare a digest and recommendations for the classification and nomenclature of Permian rocks of the United States." The subcommittee was instructed to invite the collaboration of the Association's Research Committee and the Permian Committee of the National Research Council.

Permian problems were discussed at the mid-year meeting of the A.A.P.G. in El Paso in the fall of 1938. This was followed by a considerable interchange of correspondence between interested members during the ensuing winter, and by a renewal of discussion at the convention in Oklahoma City in March, 1939. So much study is being devoted to the subject that the Association has authorized the publication of a special volume on the Permian.

There has been great diversity of opinion and usage in the nomenclature and correlation of Permian rocks in the United States. The task of this subcommittee was to bring as much order as possible out of the confusion in usage among members of this Association—not in an attempt to legislate for them or for the science, but primarily to provide a common standard of reference for the many authors contemplating preparation of papers for publication in the special Permian volume.

The members of the subcommittee first gave individual study to so much of the prior discussion as was available to them in published form, in manuscripts, or in correspondence in Mr. Bartram's files and those of R. K. DeFord, editor of the forthcoming Permian volume. A digest of correspondence was prepared, constituting a review of the subject referred to the subcommittee.

A preliminary report was prepared by the subcommittee in a ses-

[1] Manuscript received, January 8, 1940.

sion at Texas Christian University, Fort Worth, on June 17, 1939. Each point was approved by unanimous consent. Copies of that report were then submitted for criticism to each member of the parent Committee on Geologic Names and Correlations, to each member of the Research Committee of the Association, and to the Permian Committee of the National Research Council (through Dr. Carl O. Dunbar); also to members who had taken an active part in the prior discussions of this topic, to various local societies having to deal with Permian problems, and to a number of geologists of the United States Geological Survey.

Comment was received from the following geologists.

John G. Bartram
N. W. Bass
Sherwood Buckstaff
T. S. Childs, Jr.
G. E. Condra
Ira H. Cram
Morgan Davis
R. K. DeFord
C. H. Drummond
Carl O. Dunbar
K. L. Edward
H. C. Fountain
John E. Galley
Darsie A. Green
H. L. Griley
John M. Hills
S. Holliday
Bela Hubbard
G. Marshall Kay
Gentry Kidd
Philip B. King
Robert E. King
Robert M. Kleinpell
Roy P. Lehman
Henry A. Ley
E. Russell Lloyd
L. H. Lukert
A. K. Miller
H. D. Miser
S. W. Muller
N. D. Newell
W. A. Newton
Perry Olcott
Ben H. Parker
John B. Reeside, Jr.
R. E. Rettger
Robert Roth
H. G. Schenck
Gayle Scott
R. H. Sherman
John W. Skinner
D. G. Stookey
W. A. Ver Wiebe
M. P. White
James Steele Williams

The members of the subcommittee extend their sincere thanks to each of these for his welcome and salutary coöperation. Nearly every one of them proffered one or more definite suggestions, supported by argument, for improvement of the preliminary report. With most of these contributors, further letters were interchanged to clarify the questions involved. After due consideration, about half of the suggestions offered were adopted by the subcommittee, and several others were withdrawn by their authors. On the remaining few items, the subcommittee regretfully finds it impossible at this time to reconcile opposing points of view, and therefore has no choice but to embody in its revised report the considered judgment of its members—endorsed on each point by the majority of its correspondents. The chief points of unsatisfied criticism involve the definition of the top and base of the Permian system, and the use of a subsurface type locality for the proposed Ochoa series.

A brief review of the principles at issue is appended to this report. The subcommittee will welcome the publication of criticisms by those who disapprove its report in any respect.

The subcommittee unanimously offers the following recommendations.

RECOMMENDATIONS OF THE COMMITTEE

1. Permian rocks of the world should be recognized as constituting an independent geologic system, rather than a subdivision of a system.—In the subcommittee's estimation, a large majority (by any mode of measurement) of current world usage recognizes systemic rank for the Permian.

Among the intrinsic attributes which have been urged as reasons for recognition of established systems and which are possessed by the Permian also, are the following: (a) It possesses distinctive paleontologic assemblages. (b) It is set off in many regions by stratigraphic hiatuses at top and base; and locally by strong angular unconformities. (c) Its maximum thickness, including all strata of the standard section recommended in this report, exceeds 10,000 feet. Excluding all strata whose assignment to the Permian has ever been challenged, the maximum thickness of the indisputably Permian remnant exceeds 5,000 feet. (d) In various parts of the world, the Permian deposits are characterized by a distinctive lithology including limestone reefs and unusual thicknesses of limestone, dolomite, salt, anhydrite, and redbeds. (e) By various methods of estimation, the Permian is assigned as great an interval of time as some other geologic periods, the deposits of which have been accorded worldwide official recognition as systems.

In each of these respects the Permian equals or exceeds some of the other recognized geologic systems.

2. As an aid to satisfactory definition and correlation of major subdivisions of the Permian system in North America, a suitable Permian section on this continent should be recognized as a standard of reference.—Selection of such an American standard section of Permian rocks is designed not to supplant the type section of eastern Russia, but to be of assistance in guiding North American classification.

3. A standard section of a system should possess the following characters.—It should be fossiliferous, marine; as complete as possible; readily divisible into series by means of significant stratigraphic boundaries; well described as to stratigraphy and paleontology; preferably accessible, well exposed, and structurally simple. To reduce to a minimum the possibility of error of correlation within the standard section, it is desirable, but not obligatory, that all of its component series should be defined by type sections all of which lie within the same geologic province.

4. The Permian system of the Delaware Basin and its bordering uplifts, in West Texas and southeast New Mexico, should be utilized as a standard of reference for North America.—Among described sections of

Permian rocks on this continent, that section appears best fitted for this purpose.

5. The zone of Pseudoschwagerina *and* Properrinites *should be recognized as comprising the lowest part of the Permian system.*—This zone was not incorporated in the original definition of the Permian of Russia, but its inclusion accords with a growing modern usage founded on studies in Europe, Asia, North America, and Australia. Definition of the lower and upper boundaries of the Permian system in the proposed standard section may best be based on the occurrence of diastrophic and paleontologic boundaries that are correlated with similar boundaries of greatest significance in other continents.

6. The pronounced disconformity or hiatus which in nearly every known American section separates Permian from overlying Triassic or younger strata, should be recognized as the upper boundary of the Permian system.

7. The standard series divisions currently proposed by Adams and others[2] *are recommended for general use.*—The subcommittee collaborated in preparing the definitions of these series. The following statements are quoted in part from the Adams report.

(*A*) *Wolfcamp series.*—The first and lowest of these divisions, the Wolfcamp series, includes the oldest Permian rocks of the Glass Mountain region. It comprises beds that have been referred to the Wolfcamp formation (restricted),[3] which is thus raised to series rank. In the Glass Mountains the Wolfcamp series consists of about 600 feet of limestones, limestone conglomerates, and shales. In West Texas the Wolfcamp rests with angular unconformity on rocks ranging in age from pre-Cambrian to upper Pennsylvanian, and is disconformably overlain by the succeeding Leonard series.

Although the Wolfcamp fauna includes many genera that range up from the Pennsylvanian, it is characterized by the abrupt incursion of the fusuline genera *Schwagerina* s.s., *Pseudoschwagerina*, and *Paraschwagerina*, and by the presence of the ammonoid genus *Properrinites*, the brachiopod genus *Parakeyserlingina*, and other distinctive Permian genera.

The great hiatus present at the base of the Wolfcamp in West Texas may be partly filled in regions removed from the Marathon

[2] John E. Adams, M. G. Cheney, R. K. DeFord, R. I. Dickey, C. O. Dunbar, J. M. Hills, R. E. King, E. R. Lloyd, A. K. Miller, and C. E. Needham, "Standard Permian Section of North America," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 11 (November, 1939), pp. 1673–81.

[3] Philip B. King, "Geology of the Marathon Region, Texas," *U. S. Geol. Survey Prof. Paper 187* (1937), p. 94.

disturbance, by beds older than the type Wolfcamp. In such an area the base of the Wolfcamp series may be drawn at the first important hiatus below strata characterized by the genera mentioned above, but not lower than the base of said interpolated beds.

(*B*) *Leonard series.*—The second division, the Leonard series, comprises beds heretofore described as the Leonard formation, which is thus raised to series rank. At the type locality on the south face of the Glass Mountains the Leonard is more than 1,800 feet thick and consists of limestones and dark siliceous shales. It rests disconformably on the underlying Wolfcamp and underlies the Word formation of lower Guadalupe age with seeming conformity; although local basal conglomerate is reported in the Word.

In the Leonard series *Prorichthofenia* and *Scacchinella* are common brachiopods. *Dictyoclostus bassi* McKee (=*Productus ivesi* of authors, not Newberry) is a common, diagnostic species; *Perrinites* is representative of the ammonoids; and the dominant fusulines are primitive types of *Parafusulina.*

(*C*) *Guadalupe series.*—The third or Guadalupe series includes 3,000 to 5,500 feet of marine beds that overlie the Leonard series in the southern Guadalupe Mountains and adjacent areas. These beds have heretofore been described as part of the Guadalupe group. The Guadalupe group is here restricted to exclude beds of Leonard age, and is redefined as a series.

The Guadalupe series in and around the Delaware Basin can be subdivided into two paleontologic units. The lower unit, which includes the Word formation and the equivalent lower and middle portions of the Delaware Mountain sandstone, together with limestones of the same age in adjacent areas, contains the ammonoid *Waagenoceras* and is characterized by species of the genus *Parafusulina* that are markedly more advanced than the primitive species of the same genus in the underlying Leonard series. In the upper unit, which includes the Capitan limestone and the equivalent upper portion of the Delaware Mountain sandstone, the fusulinid genus *Polydiexodina* is prominent and characteristic. The more advanced ammonoid *Timorites* replaces the related genus *Waagenoceras*, although both may be present in the basal beds.

(*D*) *Ochoa series.*—It is proposed to define a fourth and uppermost division of the Permian, called the Ochoa series after Ochoa post office in T. 24 S., R. 34 E., Lea County, New Mexico. This series is intended to include all upper Permian sediments of post-Guadalupe age. It consists largely of evaporites and attains a subsurface thickness of

considerably more than 4,000 feet. Almost continuous deposition took place during Ochoa time in the deep basin underlying the type locality.

Four distinct subdivisions of the Ochoa series are designated, in ascending order, as the Castile (of Lang;[4] Lower Castile of earlier authors), the Salado (of Lang;[5] Upper Castile of earlier authors), the Rustler, and the Dewey Lake.

The Castile is confined to the Delaware Basin, where it rests on the Guadalupe series. In places a basal conglomerate is present. Outside the Delaware Basin the Salado overlaps onto and rests unconformably on beds of Guadalupe age.

Outcrops of beds of Ochoa age are found in Eddy County, New Mexico, and Culberson County, Texas, but these outcrops represent only part of the thick sequence found in the subsurface type locality. The type section has been drilled in hundreds of wells, and is represented by samples and by thousands of feet of cores on file at the Bureau of Economic Geology, Austin, Texas.

Only a few undeterminable pelecypods have been found in the Rustler limestone. The remainder of the series appears to be unfossiliferous. The exact position of the top of the Permian therefore has not been determined paleontologically in this region. Unfortunately, no adequately fossiliferous sequence, definitely of Ochoa age, is yet known to exist in North America; and no better type section is known for this series.

General comment on the standard section.—The terms "Lower," "Middle," and "Upper Permian" are deliberately left undefined, and therefore available for use in a general rather than a specific sense.

It is recognized that any standard section, though it may now appear the best which can be devised, must remain subject to later revision. Its adoption, if merited, is but a forward step in the clarification and systematization of our increasing knowledge.

Problems of correlation.—The subcommittee believes that the paleontologic and stratigraphic evidence in hand is sufficient to justify the application of some of the proposed standard series names to correlative sequences of rocks along the eastern margin of the Permian Basin from Texas to Nebraska. It is desirable to use the same series names over as wide an area as practicable.

It is recognized that outside of the West Texas-New Mexico province in which the standard section lies, the precise limits of the standard series in other provinces can not yet be set with finality, but must remain subject to corrective adjustment in many places.

[4,5] Walter B. Lang, "Salado Formation of the Permian Basin," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23, No. 10 (October, 1939), pp. 1569–72.

Part II. Review of Stratigraphic Principles

1. WHAT IS A GEOLOGIC SYSTEM?

Correspondence received by the subcommittee indicates three different concepts as to the fundamental nature of a geologic system. Different groups of writers stressed respectively its character as an assemblage of rocks distinguished (1) by diastrophic criteria, or (2) by paleontologic content, or (3) by chronologic span fixed by original definition or by usage.

In 1932 the following definitions and comments were prepared by a joint committee of American geological organizations.[6]

Article 2.—The following divisions or units of rocks are recognized: (1) *System*, a standard, world-wide division; contains the rocks formed during the fundamental chronologic unit, a period. (See Article 24.) Example, *Devonian system.*[7]

Article 24.—The following divisions of geologic time are recognized: . . . (2) *Period*, the fundamental unit of the standard geologic time scale, the time during which a standard system of rocks was formed. Example, *Devonian period.*[8]

These statements define *system* and *period* reciprocally, each in terms of the other,—system as a rock unit, period as the corresponding time unit. Although that leaves the reader in doubt as to whether the time concept or the stratigraphic one is prerequisite to the other, it expresses a very real interdependence of the two in geologic usage. This is further explained in the following supplementary remarks.

Following Article 2.—(e) Systems . . . imply a time element as an essential feature in their discrimination.[9]

Following Article 24.—(b) The names applied to the periods are derived from the names of rock units in specific regions, mainly in western Europe—that is, the time included in the period is, theoretically, that time during which was being formed the specific rock unit from which the name came. Actually the type region may contain only a part of the full sequence assigned, in general usage, to the particular system—for example, the Devonian of Devonshire, England—but it is customary to select other regions where the sequence is more nearly complete to supplement the type regions and to erect, thereby, a composite practical standard. Thus, the working concept is formed of the standard unit of time corresponding to the standard sequence

[6] The Association of American State Geologists, the United States Geological Survey, The American Association of Petroleum Geologists, and the Geological Society of America. G. H. Ashley *et al.*, "Report on Classification and Nomenclature of Rock Units," *Bull. Geol. Soc. America*, Vol. 44 (1933), pp. 423–59. *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17 (1933), pp. 843–68; reprinted in Vol. 23 (1939), pp. 1068–88.

[7] *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 23 (1939), p. 1074.

[8] *Ibid.*, p. 1087.

[9] *Ibid.*, p. 1075.

of rocks. In these rocks occur fossils that serve as a means of referring other sequences to the standard time unit.[10]

The intimate interrelation of the rock and time concepts is evident from such phrasing as "referring . . . sequences of *rocks* to the standard *time* unit." In reverse the committee refers to "standard time units based upon a standard stratigraphic scale."[11] As the nuclear concept of each period comprised the time occupied by the formation of a certain rock sequence, the stratigraphic unit appears to be prerequisite to the time unit; and yet the concept of continuous geologic time, divided for convenience into periods without nameless gaps between them, has compelled recognition that a period may exceed in length the time occupied by formation of the standard rock sequence from which the period was named. Therefore, the system called by the same name may contain, away from the type section, rocks formed within the limits of the period but slightly older or younger than any in the type section, or dating from a time represented only by hiatus within that section. Although recognizing the usefulness of names for gaps such as the Lipalian interval, the joint committee denied them a part in formal stratigraphic nomenclature.[12]

All the named subdivisions of geologic time have been defined in terms of rocks or their contained fossil faunas and floras, or of the relations between rock sequences or between successive biota. Emphasis on the paleontologic factor is justified by its unique value for long-range correlation, and by the fact that distinctiveness of fossil content has been one of the attributes urged as justifying systemic rank for each post-Algonkian system. Other such attributes have been structural relations, such as the presence of bounding unconformities in the type area; and lithologic distinctiveness from adjacent parts of the geologic column. Substantial thickness usually has been cited as a supporting feature. Each of these four attributes, in proportion to its development, may have time significance—as implying either great length of time or the presence of contemporary conditions so distinctive as to warrant treatment as a separate chapter of earth history. As in human history, distinctiveness seems to be accorded more weight than simple duration as a basis for choosing time units of prime significance. In the matter of duration, the best available estimates accord to the Permian a longer span of time than to some other well recognized periods.[13]

[10] *Ibid.*, p. 1087.

[11] *Ibid.*, p. 1086.

[12] *Ibid.*, Article 26, p. 1088.

[13] A. C. Lane *et al.*, "Report of the Committee on the Measurement of Geologic Time," *Nat. Research Council Div. Geology and Geography, Ann. Rept. 1934*, app.K.

In the judgment of the subcommittee, the Permian sediments of the world possess all of these qualifications for systemic rank, and fulfill the above quoted definition of a geologic system.

The Permian already is accepted as a system in most official usage in Europe and Asia, and by many of the American State surveys. This wide recognition is regarded by some of our correspondents and by part of the subcommittee as more vital than the objective qualifications above outlined, in establishing the Permian as entitled to systemic rank. The following discussion of the relative importance of priority, usage, and objective fact in determining the boundaries of a system is also pertinent to the question of its systemic status.

2. HOW SHOULD THE LIMITS OF A GEOLOGIC SYSTEM BE DEFINED?

Discussion of this question, with especial reference to determining the proper boundaries of the Permian system in the proposed auxiliary standard section, occupied some hundreds of pages of correspondence between the members of the subcommittee and its many coöperators. The following are among the chief factors cited in that correspondence as influencing the selection of those boundaries.

1. Priority
   (A) The original definition of the system in its type locality
   (B) Data from other regions cited by the original proponent of the system in discussing its title to systemic rank. Its relation to contiguous systems as originally defined in *their* type localities
2. Usage.
   (A) In the type area of the system
   (B) Throughout the world
3. Objective facts
   (A) The most natural boundaries now determinable in the type area
   (B) The most natural boundaries now determinable on the basis of all known evidence throughout the world

Priority.—All participants in the discussion accept the original definition of the system as the starting-point for study of the problem. but few of them would exclude all other factors from consideration. Few would deny to later students the right to revise, in the light of greatly increased evidence, by methods similar to those applied by the original author, the conclusions he reached as to the proper boundaries of a system. No modern Russian geologist considers himself strictly bound by Murchison's original definition of the Permian system in the type area. Soviet geologists have engaged in lively debate as to its proper boundaries, founding their arguments on naturalistic evidence more than on usage or priority.[14]

[14] James Steele Williams, "Pre-Congress Permian Conference in the U.S.S.R.," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22 (1938), pp. 771–76. See also "Abstracts of Papers," published in English by the Seventeenth International Geological Congress (Moscow, 1937), pp. 81–111.

The point has been made that only by strict adherence to a single unchangeable definition in terms of an original type section, can the time occupied by a system be limited accurately and uniformly throughout the world. That is impracticable as yet, if each period is considered to be contiguous in time with the next earlier period and the next later one. Outside the type areas of two systems, one superjacent to the other, there may exist sediments which are not represented in either type area except by a hiatus. In practice, such sediments either have been assigned to one of the two previously recognized systems, or divided between them, or set up as a new and separate interpolated system.

On the other hand, it is possible that the geographically separated type sections of two successive systems may later be found to overlap in time. In such case, the one later established would be restricted by transfer of the overlapping portion to the other system, unless naturalistic evidence for a different position of the boundary were deemed sufficient to outweigh the claim of priority. Certain sediments formerly assigned to the upper Permian of Russia are now placed in the Triassic on fossil evidence.[15] This shift constitutes a correction to the original definition of the type Permian.

The ideas of the original author of a system concerning its representation outside the type locality, and its relations to other systems, are regarded with respect as supplementing and clarifying his definition of the system, but can not be held sacrosanct. Beneath the type Permian of Russia as originally defined lies a sequence of sediments then correlated by Murchison with the Upper Carboniferous of England. Part of these now are known to be younger than any part of the Carboniferous type section.[16] Most stratigraphers, both Russian and foreign, now assign at least part of them to the Permian system.

Usage.—A number of correspondents felt that in selecting the limits of the Permian the subcommittee should be guided by the current opinion of those most familiar with the type section in eastern Russia, and best qualified to judge as to its proper limits there. Difficulty in giving exclusive weight to this factor arises from the fact that various recent Russian writers have drawn the base of the Permian in the type area at four different horizons, spread through a wide stratigraphic and paleontological range.[17] No majority of these au-

[15] Carl O. Dunbar, "The Type Permian: Its Classification and Correlation," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 2 (February, 1940), pp. 237–81.

[16] *Cf.* Carl O. Dunbar, *op. cit.* Also R. C. Moore, "Carboniferous-Permian Boundary," *ibid.*, pp. 282–336.

[17] *Cf.* James Steele Williams, *op. cit.*; also "Abstracts of Papers," *XVII Int. Geol. Cong.*, pp. 81–111.

thors is apparent for any one horizon, although published comment indicates a majority in favor of horizons higher than that chosen by this subcommittee.

We hope, however, that our Russian colleagues will be pleased to learn that we favor recognition of maximum extent for the one geologic system first established in their homeland.

Radically different appraisals of contemporary Russian opinion were made by different American participants in last summer's discussion, and vigorous debate ensued among them. Seven of them had the advantage of attendance at the International Geological Congress in Russia in 1937. Before the Congress, they differed among themselves in opinion as to the probable proper position of the base of the Permian. They still differ. In a manner delightfully human, each of the seven is inclined to feel not only that a majority of Russian geologists now agrees with him, but that the Russian whose opinion deserves greatest respect is one of those who so agrees. A majority of this group of American correspondents approves the report of the subcommittee with respect to the proper base of the Permian.

The decision of the subcommittee was influenced also by factors other than its appraisal of current Russian usage. Each of the Russian geologists who have discussed this subject in print in recent years, has based his opinion less on usage, than on objective facts tending to establish a natural boundary—such facts as paleontologic breaks, faunal affiliations, hiatuses or unconformities, and lithologic changes. Hence in appraising the usage of these authors, one is also appraising objective facts indirectly, through direct studies made by them.

Some correspondents have given consideration to worldwide usage as well as to usage in the type area. A system, by definition,[18] should include rocks formed within a period bounded by the same time limits throughout the world. As the type section admittedly may be incomplete, study of a system throughout the world is necessary to a full definition of it. The worldwide data, like the data concerning the type area, may be appraised indirectly by measuring usage.

Objective facts.—Although nearly all pertinent usage is founded wholly or in part on study of objective fact, some of our commentators regard usage as more important than the facts on which it is founded, as a factor in determining the proper position of the base of the Permian system. This attitude is based less upon faith in any inherent virtue possessed by usage, than on lack of faith in the existence of a logical natural basis for selection of any boundary in preference to another. An extreme example is the contention that one could re-

[18] *Cf.* p. 345, *supra.*

divide all geologic time into period units with boundaries lying about midway between those of the periods now commonly recognized; and that the resulting newly defined systems would be just as distinctive, one from another, as those now in use, and would possess boundaries just as clearly marked.

This thesis is defended upon both paleontological and diastrophic grounds. If we possessed a complete paleontological record, we presumably would find no sudden worldwide replacements of faunal or floral assemblages of new types, but only gradual evolutionary changes. The rate of change doubtless varied, but we have little assurance that the period boundaries now recognized coincide with times of actual, and not merely apparent, rapid change.

The boundaries of the recognized geologic systems, in general, were placed originally at structural, lithologic, or paleontologic breaks in the geologic columns of the regions where they first were studied. But some correspondents assert that those boundaries, in the worldwide view, are no more significant than many intervening ones. They regard the selection of systemic boundaries as a largely arbitrary matter, without consistent foundation in fact. They suggest that naturalistic evidence be wholly disregarded in that connection, and that complete reliance be placed upon existing usage, as in itself the test of propriety.

But the premises of that argument are open to debate. Current usage in this matter is founded in the main, whether soundly or not, upon objective fact. All past changes in usage have resulted from arguments founded on the presentation of new facts or improved understanding of old ones. The systems which have achieved wide usage constitute readily differentiable units in many parts of the world, and their usage has persisted for that reason. The field is open for further improvement in the naturalistic analysis of the geologic column and of geologic history.[19]

The natural foundation of the periodic divisions of geologic time now in general use comprises many elements—paleontologic, diastrophic, climatologic, geographic, and lithologic. Effective defense may be made of the thesis that there exists adequate natural basis for division of geologic time into distinctive chapters—though in places one chapter may appear to grade into another, and we may not yet have attained sufficient understanding to perceive in full the ideal division into chapters.

[19] "In science most advances are made by minorities with new observations and new facts to guide them. The fact that an idea is generally accepted should carry small weight with scientists. . . . Objective facts must dictate." Carl O. Dunbar, letter to C. W. Tomlinson, August 25, 1939.

To cite but a single example of such naturalistic defense in the several pertinent fields of knowledge, let us presume the establishment of a new period extending from mid-Cretaceous to mid-Eocene or mid-Tertiary time. Could its fauna possibly be regarded as constituting so natural a unit as that of either of the periods so dissected? It would straddle the jump from reptilian to mammalian dominance. It would begin before the Laramide Revolution and end after its close, extending into quiescent times before and after. It would reach from a time of maximum to one of almost minimum submergence. It might divide between two systems the chalks which lent their name to the Cretaceous system and which characterize it in more than one continent.

Lithologic criteria commonly occupy a place of relatively small importance among evidence pertinent to selection of systemic boundaries. They are always subject to revaluation in the light of critical evidence of other sorts. There are few readily distinguishable kinds of sedimentary rock which do not appear in more than one geologic system. Lithology is worthy of mention in this connection, however, bebecause a widespread deposit of distinctive character reflects correspondingly widespread and distinctive conditions of origin. Of the many types of such deposits, some have much greater development in one or two geologic systems than in any others; and thereby constitute a recognized characteristic feature of those systems. It is the lithology of the Permian, dated and supplemented by its paleontology, which paints for us much of that fascinating self-portrait of a strange world—its subtropical (?) ice-sheets, its vast red plains of deposition, its sweet and bitter seas, its fringing reefs, its arid reaches and its humid lands. The complete picture is distinctive and unique, though every element in it occurs in other systems also; just as wholly different paintings may be developed from the same assortment of pigments. But though vital to the picture as a whole, lithology serves but poorly as an aid in fixing the boundaries of the Permian system. For example, very extensive redbeds occur in the Triassic as well as in the Permian, and the Pennsylvanian also includes a substantial volume of such strata.

Does the diastrophic record afford a natural basis for the division of the geologic column? The theory of diastrophic periodicity persists[20] in spite of divergent opinion,[21] though its proponents have varying conceptions as to the duration and regularity of the diastrophic

[20] *Cf.* W. H. Bucher, *The Deformation of the Earth's Crust*, Princeton University Press (1933); especially Chapter V, "The Diastrophic Cycle," pp. 125–48.

[21] *Cf.* F. P. Shepard, "To Question the Theory of Periodic Diastrophism," *Jour. Geol.*, Vol. 31 (1923), pp. 599–613.

cycle. On such a basis, Grabau[22] would subdivide the rocks of the Paleozoic era into fourteen systems instead of six (current European usage) or seven (common American usage). Others suggest as more important a still briefer cycle, corresponding to a geologic series rather than a system. Considering the whole world, they would attach as much significance to diastrophic movements marking series boundaries, as to those at systemic boundaries.

Although both stratigraphic and structural evidence of the span of time occupied by diastrophic events has been accumulating rapidly, many orogenies can not yet be dated accurately enough to settle the question of their time relation to periodic boundaries. For some mountain chains it can be demonstrated that the creation of the chain involved several episodes spread through a span of time comparable to that occupied by a geologic period, or a large fraction of a period. In some regions, a whole period may have been occupied by continuous or intermittent diastrophism on a scale not approached in that part of the earth's crust at any other time in its legible geologic history. That was true, for example, of Pennsylvanian time in an area of 200,000 square miles in the southern Great Plains centering about the Arbuckle and Wichita mountains. Such a record suggests the differentiation of a whole period, rather than only its initial and terminal episodes, as a time of mountain-building. Each such episode appears to be represented by obscure but significant disconformities far outside the orogenic belt.

At the base of the Permian system as defined by the subcommittee there is sharp angular unconformity in many regions, and still more widespread hiatus. In several localities in the southwestern United States, it marks fairly accurately the close of the Pennsylvanian orogenies above mentioned.

Some of our correspondents, stressing the biotic aspect of geologic history, place little weight on diastrophic criteria, but seek in paleontologic data a sufficient natural basis for determination of the most suitable systemic boundaries. Most of the recent Russian papers discussing the base of the Permian have weighed paleontologic data, almost to the exclusion of other considerations. Their arguments, like those of many American contributors to the debate, proceed on the assumption that the boundary should be drawn at that point in the column, regardless of other factors, where the most significant and extensive paleontologic changes take place. Among objective data, the

[22] A. W. Grabau, *Palaeozoic Formations in the Light of the Pulsation Theory*, Vol. IV (Henry Vetch, Peking, 1938), reviewed by R. E. Janssen in *Jour. Geol.*, Vol. 47 (October, 1939), pp. 779–80.

subcommittee has attached greatest weight to this type of evidence. Although there still is difference of opinion in the application of this principle to determination of the base of the Permian, most of our paleontological correspondents approve the subcommittee's selection as the most logical that can now be drawn on this basis.

Such a choice may be equally satisfactory from other points of view. A horizon of significant paleontologic change is apt to be marked also by hiatus or unconformity. More than one of the positions which has been recommended for consideration as a suitable base for the Permian is believed to be clearly marked in more than one continent by paleontologic or stratigraphic breaks, or by both—and none more generally so than the one here endorsed. Widespread ease of recognition is urged as a practical advantage for such horizons.

This method of approach to the problem of course is unpalatable to those who demand that stratigraphic classifications be based on ideally *complete* sections, devoid of breaks. The more complete the section above and below a systemic boundary, the more difficult it becomes to decide upon the exact position of the boundary—either by paleontologic or by diastrophic means.

Relation of principles to definition of Permian boundaries.—In selecting the limits of the Permian system in the proposed American auxiliary standard section, the subcommittee has not regarded priority as the most critical element in definition of boundaries. It has been guided chiefly by interpretation of objective fact and has been influenced largely by usage. Judgment that the limits initially proposed for the Permian system are subject to revision is supported by almost universal acceptance during more than a half century of an addition of beds (Artinsk) occurring below the original Permian, and by general acceptance by geologists of removal of deposits from the upper part of the original Permian that are found to contain distinctive Triassic fossil remains. Definition of the boundaries of the Permian system in the American standard section has been based on evaluation of stratigraphic observations, including evidences of paleontologic, diastrophic, and, to some extent, lithologic nature, as reported both in this continent and others. The lower boundary accords with that which has become increasingly established by American usage and appears to agree with the lower boundary in the Russian type section that is advocated by a number of geologists. It does not correspond to the boundary that has generally been recognized by Europeans, or, so far as can be learned, that is supported by majority of current usage in Russia. Accordingly, acceptance of the proposed lower boundary of the Permian requires revision of classification by many workers in

some sections. The upper boundary of the system is determined on physical grounds, and absence of fossils in youngest beds that are tentatively referred to the Permian in some American sections prevents satisfactory correlation with other sections.

In summary, it appears to the subcommittee that priority has been respected as determining the name and approximate span of major stratigraphic divisions, such as systems, but not as fixing or "freezing" boundaries. Usage may undergo change. It is influenced, especially in early stages of the history of a term, by priority, but increasingly it is likely to take account of objective facts as determined by studies in all sections. Revision of definitions is generally recognized as allowable and needful, and new definitions become established by usage. Some geologists are disposed to deny that basis for "natural" division of rocks into systems exists, and it is held that one arbitrarily fixed classification may be about as useful as another. This view is not acceptable to the subcommittee, which concludes from its survey that, under human limitations of observation and interpretation, objective fact is the ultimate foundation of most original definitions and of nearly all past and current usage. Thus, analysis of stratigraphic evidence supplemented by an appraisal of past and current usage is believed to furnish the best guide to development of a classification that is "natural" and practically useful.

It is probable that the work of the subcommittee reflects the pragmatic spirit which is fostered by the commercial employment of most of the members of our Association. The subcommittee has striven to reach results which would be of maximum usefulness at this time, rather than to set up now an ideal of perfection that may never be attained.

3. SHOULD ROCKS OF DEBATABLE SYSTEMIC AFFILIATIONS BE EXCLUDED FROM A STANDARD SECTION OF A SYSTEM?

It is generally agreed that a standard section should be as complete as possible, so far as that ideal is attainable without undue loss of other characters which such a section should possess. It seems more useful and practical, therefore, to select for present use those definite boundaries which now seem most logical, rather than to leave some rocks unassigned, or to indicate questioned systemic placement.

The subcommittee freely recognizes the desirability of future adjustments of these boundaries if evidence comes to light sufficient to warrant such a change. In the meantime it is advantageous to possess as definite a standard of reference as possible. The subcommittee therefore chose to place in the Permian without question marks those

rocks which, in the light of present evidence as they appraise it, actually belong there. The question marks may be regarded as implicit in the fluidity and flexibility of usage in a rapidly growing science. The present selections may serve at least as landmarks. They are discussed separately in the following passages:

A. The base of the Permian.—The sharpest debate on this matter hinged upon inclusion of the Wolfcamp series in the American standard section. Objective evidence in the affirmative is well summarized in the following statement to the subcommittee by Carl O. Dunbar.

> The "*Pseudoschwagerina* complex" marks a distinct horizon that can be recognized in most parts of the world where fusulines are represented. This fact I believe all will agree to; it is the horizon of the Wolfcamp in America, the Sakmarian in Russia, the Schwagerinakalk of the Alps, the Chuanshan of south China and its equivalent in Indo-China. In many parts of the world it follows a great hiatus. In the southwestern part of the U.S.A. it is separated from the Pennsylvanian beds by profound unconformity in the Glass Mountains and by angular discordance of varying degrees farther west in Texas and New Mexico. These beds overlap onto the pre-Cambrian in West Texas and in places in New Mexico, and in northern California rest disconformably on the Lower Carboniferous (i.e., McCloud limestone on Baird limestone). Over a vast area in the Orient the Chuanshan and its equivalents rest on beds of Moscovian (Des Moines) age or older. In south China it is the Chuanshan on the Huanglung limestone and in Indo-China it is the equivalents of these units. Fromaget has shown that there was a great change in paleogeography and extensive igneous activity in Indo-China during this interval. In short, the horizon represented by the Missouri and Virgil series of the U.S.A. is missing throughout south China and Indo-China. In South America this horizon rests upon much older rocks. The situation in the Permian Basin of the U.S.S.R. is discussed in detail in the writer's manuscript on "The Type Permian." The *zone of Triticites* is well represented there and probably no great hiatus exists over the deeper part of the basin between the base of the Middle Carboniferous and the top of the Permian. In this respect the situation resembles that in the northern Mid-Continent region.
>
> Throughout its whole sweep the *zone of Pseudoschwagerina* is characterized not by one genus or one species, but by a complex of species of the genera *Schwagerina, Pseudoschwagerina* and *Paraschwagerina.* This represents a great evolutional outburst in the family Fusulinidae. These forms appear abruptly above the hiatus noted above and become "worldwide" in their distribution. The underlying strata which constitute our Upper Pennsylvaian (i.e., Canyon and Cisco or Missouri and Virgil groups) having a thickness of several hundred feet are characterized by various species of the genus *Triticites* with none of the genera mentioned above. The *zone of Triticites* is easily recognized in other parts of the world wherever its horizon is represented by marine strata. It is true that the genus *Triticites* holds over into the *zone of Pseudoschwagerina* and gradually dies out, but with the local exception noted by Rauser-Chernoussova I do not know of any species which crosses that boundary. The faunal break above the *zone of Pseudoschwagerina* is one of gradual restriction and a very gradual evolution of the septal folds

from the stage of *Schwagerina* s.s. to that of *Parafusulina*. It is my measured judgment that, considering the world in the large, the fusuline faunal break, like the stratigraphic hiatus, is far greater below than above the *zone of Pseudoschwagerina*.

As for the ammonites, the two most experienced and most able specialists are agreed and have presented their views that the greatest break is below the Wolfcamp and the Sakmarian. I refer to Ružencev in the U.S.S.R. and Miller in the U.S.A.[23]

For more exhaustive discussion of this question, including the factors of priority and usage as well as objective fact, the reader is referred to current articles by Dunbar and by Moore.[24]

Although most correspondents concurred in regarding the base of the Wolfcamp series as the most suitable base for the Permian on objective evidence, a few felt that this series should be labeled "Permian?" or "Permian or Carboniferous" for the present. These commentators were among those who hold that current usage in the original type locality of the system should be the sole or the chief guide to propriety in this matter. Their appraisal of that usage was contested by other participants in the discussion.

B. The top of the Permian.—It is admitted that deficiency of paleontologic data in sediments adjacent to the upper boundary of the Permian in the West Texas region leaves that boundary still more open to question. Sequential, lithologic, and structural relationships, with scant faunal and floral evidence, furnish the only available basis for correlation of the Ochoa series with the Upper Permian section of similar facies in Russia, and for determination of its upper boundary. The best that can be said for the boundary chosen is that it conforms to all evidence known to the subcommittee at this time. A few correspondents, on the strength of long-range correlations, believe that it should be lowered in the section. Others question both the validity of those correlations and the age of the distant strata with which correlation is attempted. It is probable that increasing data will shed more light on the proper position of this boundary. If it should be lowered, the Ochoa series should be correspondingly restricted or divided.

4. MAY A STANDARD SECTION INCLUDE ELEMENTS WHICH DO NOT POSSESS IDEAL CHARACTERISTICS FOR THAT PURPOSE?

The following specific problems of this general character required action by the subcommittee.

[23] Carl O. Dunbar, letter to C. W. Tomlinson, August 25, 1939.

[24] Carl O. Dunbar, "The Type Permian: Its Classification and Correlation," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 2 (February, 1940), pp. 237–81.
R. C. Moore, "Carboniferous-Permian Boundary," *ibid.*, pp. 282–336.

A. Should a series be excluded from a standard section because it is nonmarine and lacks fossil faunas adequate for accurate correlation?—The subcommittee has been charged with inconsistency for listing abundance of marine fossils as one of the desirable attributes of a standard section, and yet including in the suggested auxiliary standard section of the Permian the proposed Ochoa series, a sequence lacking in that regard. The answer is, what else can now be done with it? In lithology, depositional environment, and probably as representing approximately the same chapter of earth history, it corresponds to the most distinctive portion of the type Permian of Russia. So far as the subcommittee is informed, no described fossiliferous marine section is yet definitely known to cover the same span of time. But that time existed, and is represented by a great thickness of distinctive sediments. Neither the time nor the sediments should be left nameless. No correspondent has offered a practicable alternative course in this regard.

B. Should chaotic and fragmentary surface exposures of a series be preferred to a far more complete, orderly, and better known subsurface section as a type locality for the series?—The following statements summarize the reasons for the negative answer of the subcommittee with respect to the Ochoa series.

It is, of course, possible to choose a very untypical "type" locality among the jumbled gypsum hills of Eddy County, New Mexico, or Culberson County, Texas, and to name the series from some nearby geographic feature; but it is not possible to define it and describe it adequately without reference to the thick and neatly regular subsurface sequence.[25]

The subsurface definition of the Ochoa series is based upon cores and upon cuttings from cable-tool wells. Some 200 complete sets of samples and thousands of feet of cores are available from wells widely distributed over the Delaware Basin, the area in which the Ochoa series is most typically developed. Additional thousands of sets of cable-tool samples from wells penetrating the Ochoa section in adjacent portions of the Permian basin are available and have been studied. These clean-cut sections give a much better picture of the Ochoa series than could be obtained from a partially exposed, badly weathered surface section which must be observed in isolated patches over a distance of more than 100 miles.[26]

Easily soluble evaporites such as comprise a large part of the Ochoa series inevitably have poor representation or none, in surface outcrops. Furthermore, extensive removal of these deposits by solution near the surface withdraws support from overlying clastic sediments, disturbing their structure. Only a minor fraction of the Ochoa series is known to occur at the surface at all, even in the "jumbled" condition described by DeFord.

[25] Ronald K. DeFord, letter to C. W. Tomlinson, August 11, 1939.

[26] John Emery Adams, letters to C. W. Tomlinson, July 24 and December 13, 1939.

5. MUST A STANDARD SECTION BE COMPLETE, WITHOUT INTERNAL OR MARGINAL HIATUSES?

Some correspondents have argued that no sequence of strata which is bounded by unconformity or by evidence of hiatus is suitable for a type section of any system, because it is obvious that such a section is incomplete. The subcommittee recognizes, in Recommendation 3, that a standard section should be "as complete as possible," and believes it has selected such a section of the Permian system of the United States. Unfortunately, it is not likely that there exists on any land area a complete section of any system, without hiatus either within it or at its boundaries. Lacking access to an ideal complete standard section, we must use an incomplete one or do without.

On the other side of that question it has been contended that a sequence bounded by discernible hiatuses is preferable for the standard section of a system, and also for that of a series, because its boundaries are less open to question at the type locality, and it is less likely to include strata which, in the light of later evidence from other parts of the world, might with equal or greater propriety be attached to an adjacent system or series.

6. WHAT NAMES ARE SUITABLE FOR STRATIGRAPHIC USE, AND WHAT CHANGES IN THEIR USAGE ARE PERMISSIBLE?

A. What order of magnitude and permanence must a geographic name possess to make its use permissible as a stratigraphic name?—The name Ochoa is taken from a ranch post-office in semi-arid surroundings. Such establishments may be moved or abandoned. More permanence can be assured to the name by assigning it to an adjacent low ridge or to the bluff at the ridge-end nearest the post-office. There is much precedent for such subterfuge where named natural features are scarce in proportion to the need for stratigraphic titles. No better unpreempted geographic name has been offered from the Ochoa region.

Among Taff's original names for stratigraphic units in the Arbuckle mountain region, those of four successive formations (as he called them)—Simpson, Viola, Sylvan, and Hunton—were derived from villages which since then have disappeared. But their former location is known and on record, and the stratigraphic use of these names is not hampered in the least by the disappearance of the corresponding settlements. Their use may be altered or dropped with advancing stratigraphic study, but not for that reason. They are among the most used of American stratigraphic names.

B. May the name of a sequence of sediments, first considered as a formation, be used later as a series name?—The first stratigraphic work in

any region usually is in the nature of reconnaissance, and is followed at later dates by more detailed description, with correspondingly greater complexity of nomenclature. In many regions units first described as formations have been treated later without change of name, as groups containing several formations. The 1933 joint committee of American geological organizations specifically recognized such procedure as permissible, in the following language.

Article 11.—The rank of a unit, where circumstances dictate, may be changed without changing its name or its content of rocks.[27]

Some correspondents would apply in such cases strict rules of priority similar to those in effect in biological nomenclature. They would prefer, as a rule, the creation of new names to the amending of old definitions. But it is the judgment of the subcommittee that less confusion will be brought about by using the name Leonard for the series of sediments formerly described as the Leonard formation, than by introducing a new term. The same procedure has been followed with the term Wolfcamp. The subcommittee fails to see any likelihood that confusion will arise in these cases from the fact that series names are employed for the corresponding time units as well as for the rocks involved. Substitution of the term *series* for the term *formation* should be adequate in itself to insure the appropriate difference in chronologic usage.

A few correspondents feel that stratigraphic terms (like *series*) designed to be of unvarying time significance are of a wholly different order from cartographic terms (such as *formation*) whose age limits may vary somewhat from place to place following lithologic contacts; and that the two should not be interchangeable. Designation of entirely new stage or series names may be preferable to adaptation of old formation or group names where the latter have suffered much by confused usage or correlation, or by extraordinary variability in time value. A formation or a group must meet the requirements appropriate to a series in order to justify use of its name as a series term. Names of both kinds are of geographic derivation and are defined by reference to a type locality and a type section. A formation may be regarded as possessing definite time limits fixed by the earliest appearance of its base and the latest disappearance of its youngest member. Similarly, the actual lithologic representation of a series varies in completeness from place to place, so that the rocks belonging to it in one area are not necessarily coextensive in time of origin with those in another. They merely fall within the same maximum time limits.

[27] G. H. Ashley *et al.*, *op. cit.* (1939, reprint), p. 1080.

However, the time intervals represented by adjacent formations may overlap—a privilege denied to adjacent series.

Because the Leonard is separated into a distinct series, the Guadalupe series as defined covers less than the maximum sequence of sediments formerly described under the term "Guadalupe group." Such restriction of this group already had been proposed. All correspondents familiar with these sediments agreed, after some debate, with the committee's decision to use this name in that manner in preference to any proffered alternative. This decision is in accord with the following passage of the report of the 1933 joint committee.

Article 10.—The redefinition of a unit to change its content of rocks, where such change is demanded by later work, does not necessarily render renaming advisable.[28]

C. Should the Russian series names be applied now to the American auxiliary standard section of the Permian, instead of names of American origin?—The subcommittee recognizes the ultimate desirability of use of a single set of series names throughout the world. Nevertheless, it deems it desirable for the present to use names defined in the type region of the proposed American standard section, where their precise limits can be studied by American geologists in the field with minimum danger of error. They may be regarded as provincial[29] series unless actually found useful in a wider sphere. Some of those familiar with both consider the American section capable of more accurate correlation than the Russian.[30]

[28] G. H. Ashley *et al.*, *op. cit.*, p. 1080.

[29] G. H. Ashley *et al.*, *op. cit.*, p. 1074, "In part, the series is a convenient unit, of size approaching that of the comparable European subdivision but not necessarily equivalent to it. In this second usage, a provincial name may be applied—for example, *Comanche series, Shasta series, Cincinnatian series.*"

[30] Correspondence of the subcommittee on the subjects discussed in the foregoing report has been classified according to topic, and is now in the files of the editor of the forthcoming Permian volume, R. K. DeFord, at Midland, Texas. It may be consulted by geologists interested in similar problems.

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GEOLOGICAL NOTES

OELOE AER FAULT ZONE, SUMATRA[1]

J. WYATT DURHAM[2]
Berkeley, California

While engaged in geologic investigations in Sumatra for the Nederlandsche Pacific Petroleum Maatschappij, the writer noticed the occurrence of a large fault zone (Fig. 1) in central and northern Sumatra, probably extending at least 550 kilometers through the central mountain area. Inasmuch as no mention of it has been found in the literature, a brief description for the benefit of future workers in the area is here presented, although no detailed work has been done on it.

The writer has observed the fault at numerous places in the field extending from the village of Rao northwest beyond Taroetoeng, a distance of 250 kilometers, and from physiographic and geologic evidence (published geologic maps) it is believed to extend nearly 250 kilometers farther northwest and at least 60 kilometers more toward the southeast. Southeast of Rao the fault is believed to follow the northeast side of the valley of the Rokan Kiri River (Batang Soempoer) to not less than 30 kilometers from Fort De Kock. North of Rao it follows the course of the Batang Asik River to the Batang Loeboek, then along Aek Lemate. Next it cuts along the face of the mountains south and southwest of Siboehoean where many small streams have been offset by relatively recent movements. Here the fault is apparently a complex zone with lateral movement in different directions for individual sliver blocks as indicated by stream offsets. There has also been considerable vertical movement in this area for in general the fault is the major boundary between the Tertiary and and pre-Tertiary here and farther southeast.

From the vicinity of Siboehoean it follows the valley of the Baroemoen and Oeloe Aer rivers and along the west side of the Si Hapas valley near the village of Sipirok where it cuts through the mountains to the valley of the Batang Toroe River which it follows northwest past Taroetoeng. Where it comes into the Batang Toroe valley in the southeast it is joined by the Batang Angkola fault which parallels the valley of the Batang Gadis and Batang Angkola rivers past Padangsidempoean.

[1] Oeloe Aer is pronounced "Ooloo Ire." Manuscript received, November 16, 1939. Published by permission of Nederlandsche Pacific Petroleum Maatschappij.

[2] Department of Paleontology, University of California.

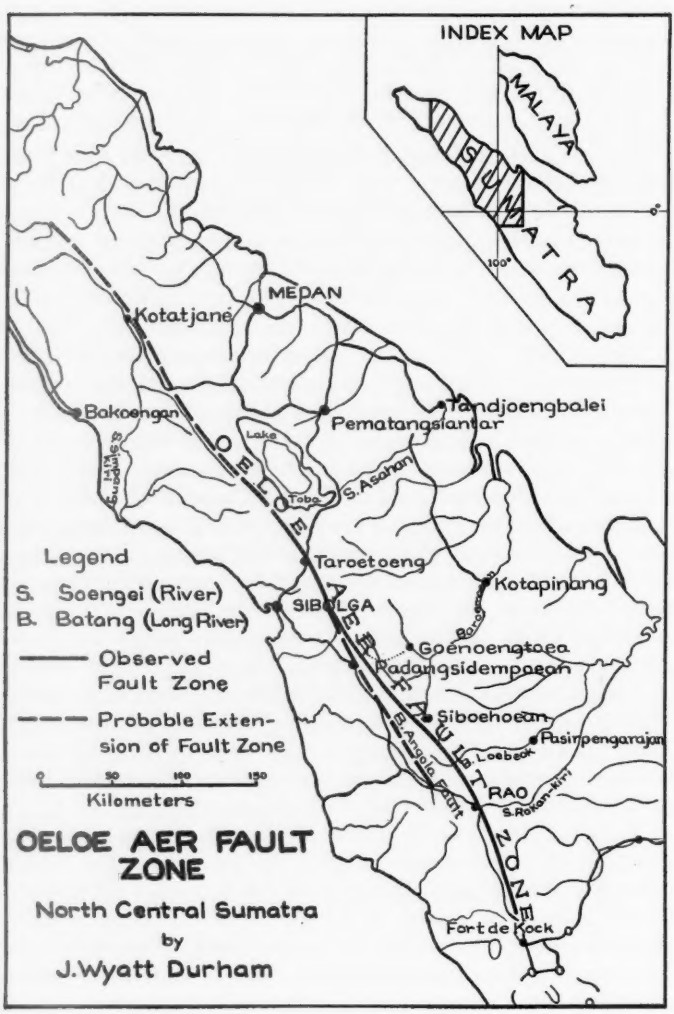
INDEX MAP
MALAYA
SUMATRA
100°
0°
MEDAN
Kotatjané
Bakoengan
Pematangsiantar
Tandjoengbalei
Lake Toba
S. Asahan
Taroetoeng
Kotapinang
SIBOLGA
Goenoengtoea
Padangsidempoean
Siboehoean
Pasirpengarajan
R. Loebeok
RAO
S. Rokan-Kiri
Fort de Kock
Legend
S. Soengei (River)
B. Batang (Long River)
Observed Fault Zone
Probable Extension of Fault Zone
0 50 100 150
Kilometers
OELOE AER FAULT ZONE
North Central Sumatra
by
J. Wyatt Durham

FIG 1

All along the fault zone from Sipirok to the place where it leaves the Batang Toroe valley northwest of Taroetoeng there are numerous hot springs and a few solfataras. Thick deposits of siliceous sinter are present in many places even where there are no active hot springs now, indicating that during the Pleistocene there was much more activity here.

Toward the northwest the fault is assumed to follow the northwest side of the valleys of two branches of the Simpang Kiri River, the "Lae Renoem" and the "W. ni Goempang" approximately 40 kilometers past Kotatjane. By referring to the geologic map of Sumatra,[3] it may be seen that the fault zone has a series of nearly east-west trending structures on its west side, with northwest-southeast structures on its east side in the area northwest of Kotatjane. Here differential movement has produced drag along the fault zone which may be interpreted as indicating movement toward the southeast on the east side of the fault.

Extending southeast from the town of Koetaradja (northwest tip of Sumatra) there is a succession of river valleys in marked alignment, suggesting that perhaps here is a farther extension of the fault zone through the central mountain area. This would extend the fault for another 250 kilometers.

The Oeloe Aer fault zone is probably part of the fault system supposed to exist along the backbone of Sumatra and of which the faults noted by Van Bemmelen[4] in South Sumatra are probably a part. In general it is parallel with the axis of the island.

Near Sipirok and approximately 35 kilometers northwest there is a sequence of highly dipping Tertiary tuffaceous clays, sandstones, and gravels. At one locality the clays contain a sparse foraminiferal fauna which, according to L. W. LeRoy,[5] indicates a probable "Lower Palembang" age (middle or upper Miocene). In view of their restricted extent these beds appear to have been deposited in a narrow basin along the fault zone, probably indicating the preëxistence of the fault. These same beds also are found south of Padangsidempoean along the Batang Angkola fault.

[3] "Geologische Overzichtskaart van den Nederlandsch Oost-Indischen Archipel," Blad I (Noord-Sumatra), *Jaarboek v. h. Mijnwezen in Ned. Oost Indie*, Verh. 1 (1919).

[4] R. W. Van Bemmelen, "De Tektonische Structuur van Zuid-Sumatra," *Natuurkundig Tijdschift voor Nederlandsch-Indie*, Deel XCIV, Afl. 1 (1934).

[5] Micropaleontologist, Nederlandsche Pacific Petroleum Maatschappij, Medan, Sumatra.

POSTSCRIPT

Since the submission of this note for publication, a paper by Van Bemmelen[6] has come to hand. In it he figures and incidentally discusses the "Semangka rift zone" extending it the length of the island through the Barisan Mountains and considers it as having formed in Plio-Pleistocene time. The accompanying sketch of the rift zone only in part coincides with the Oeloe Aer fault zone. This discrepancy is probably due in part at least to the fact that my evidence was not available to Van Bemmelen at the time he drew up his map.

[6] R. W. Van Bemmelen, "The Volcano-Tectonic Origin of Lake Toba (North Sumatra)," *De Ingenieur in Nederlandsch-Indie*, 6 de Jaargang, Nummer 9 (1939), pp. 126–40.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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STUDY GROUP REPORTS

PREFACE

With this issue of the *Bulletin* the editorial board of the A.A.P.G. is continuing a new series of informative articles entitled "Study Group Reports." We feel that it is eminently desirable to supply condensed information on practical petroleum geology problems and at the same time furnish information which is up to the minute in character.

One of the geological societies affiliated with the A.A.P.G. is the Houston Geological Society. They conceived the idea of establishing specialized groups to study certain definite problems and report on them at stated intervals of time. The subjects which were selected for special study are the following.

Surface geology	Geophysics
Subsurface geology	Structural geology
Paleontology	Mechanical well surveying
Stratigraphy	Evaluation
Sedimentation	Statistics
Paleogeography	Economics
Exploitation geology	Topography
Aerial geology	Electrical well surveying
Soil analyses	

A card was sent to approximately 300 members of the society, requesting each member to indicate which study group he preferred to join. A place was provided for first, second, and third choice. Subsequently, a steering committee of the society grouped the members according to their choice and selected a leader for each group. After studying their problem for two or three months, the conclusions reached by a certain group were put into brief form. These briefs were then published on mimeographed sheets and distributed.

With the permission of the Houston Geological Society and the members of the various groups involved, it is our privilege to republish some of these group reports. Previous reports have appeared in the August and September *Bulletin*. After reading the reports, the editor is anxious to hear from as many readers as possible to get an expression of opinion regarding (1) the desire of the members to see more of these in print, and (2) the possibility of establishing other similar study groups in other parts of the country.

W. A. VER WIEBE

ECONOMIC AND STATISTICAL ASPECTS OF THE PETROLEUM INDUSTRY[1]

REPORT OF HOUSTON GEOLOGICAL SOCIETY STUDY GROUP

R. J. GONZALEZ[2] *ET AL.*

The petroleum industry as such is approximately 80 years old, dating from Drake's discovery in 1859, but its principal development

[1] Manuscript received, December 12, 1939.

[2] Humble Oil and Refining Company, Houston, Texas. Leader of this study group.

has come within the last 40 years, as a result of the increase in motor vehicles. Production of crude oil in the United States increased from 63,600,000 barrels in 1900 to 248,500,000 barrels in 1913, and then to 770,874,000 barrels in 1926, and will be about 1,250,000,000 barrels this year (1939). During the nineteenth century the principal demand was for kerosene, but this was rapidly changed following 1900 by the increased use of fuel oil for ships and industrial plants and the use of gasoline by automobiles. In 1938, the yield of kerosene from crude was only 5.6%, while the yields of gasoline, fuel oil, and gas-oil were 44.1%, 25.3%, and 13.0%, respectively. Another measure of the increasing importance of oil and gas in industry is found in the fact that the percentage of the total mineral fuel and water power energy supplied by the products increased from 7.7% in 1899 to 26.2% in 1926, and to more than 40% in 1937. It is interesting to note that about 86% of the total installed horsepower, including automobiles and other mobile power units, depends on petroleum products. However, because automotive units are in operation much less of the time than other prime movers, probably only 40–50% of the total power actually produced in the United States comes from petroleum. Oil and gas thus rank with coal in order of importance as sources of energy in this country, although coal is much more abundant. It is estimated that coal reserves are equivalent to about 2.5 trillion tons, which is over 5,000 years' supply at the 1937 consumption rate of 494,000,000 tons, whereas petroleum reserves at the beginning of this year were estimated to be about 17 billion barrels, or less than 14 years' supply at an annual rate of $1\frac{1}{4}$ billion barrels. This contract between the supply and demand of oil and coal indicates clearly the need for conservation of oil, which is one of the principal economic characteristics of the petroleum industry.

The petroleum and mining industries possess a characteristic which distinguishes them from other important industries in that they produce irreplaceable resources. This imposes an immediate need for conservation much more clearly than in the case of other industries, and this is particularly true in the petroleum industry because of the extremely limited supply in sight. As mentioned above, it is estimated that all of the oil in the fields which have been discovered is sufficient for only about 14 years at the present rate of demand and with no changes in technology. That is not to say that at the end of 14 years all of the oil in the United States will be exhausted, for past experience has indicated that the industry will extend some fields already known and will find new fields, thus adding to the supply and prolonging the period before exhaustion. It is conceivable that at the end of 14 years

we may have found enough oil or made such improvements in techniques, either in motors or in manufacturing processes, that the number of years' supply might still be fourteen or even more. However, we have nothing at this time to indicate that such developments will take place, while on the other hand, we are faced with the likelihood that the amount of petroleum which will be found in underground reservoirs is limited, even though we do not know what the limit may be. In such circumstances, sound economic policy requires that the petroleum industry produce as efficiently as possible in order not to waste any of our known recoverable reserves. Since the production of crude oil is the cheapest method of satisfying the demand for motor fuel and lubricants at the present time, it is to the interest of the general public, as well as of the petroleum industry, that crude oil reserves should be produced in an efficient manner which will conserve them as long as possible, even though substitutes for petroleum may in time be produced commercially from oil and coal shales.

The necessity for conservation being clearly evident, it is obvious that the petroleum industry should determine and follow those practices which will result in the greatest recovery of oil from our reserves consistent with sound economic policy. It has been established that the percentage of oil which may be recovered from the total in a reservoir is influenced by producing conditions, such as the number of wells, the rate of flow, et cetera. The competitive development of oil reservoirs under the old English common law interpretation of property rights with regard to mineral resources has presented a difficult problem in the conservation of natural resources. Ordinarily an oil reservoir extends under the properties of a number of different individuals, each of whom naturally has a selfish interest in securing the largest amount of benefit to himself from the discovery of oil in the reservoir. Under the law of capture the courts have interpreted the production of oil through a well on a particular piece of property to belong to the owner of that property. This interpretation has resulted in competitive drilling to develop production rapidly either to secure as much oil as possible or to prevent drainage by other operators. In the past this situation frequently resulted in an enormous waste of capital investment, since far more wells were drilled than were required to produce the oil. In addition, the drilling of an excessive number of wells resulted in inefficient rates of production from the reservoirs and caused the ultimate recovery of crude oil from the reservoir to be much less than it should have been. This situation was contrary to the public interest and also detrimental to the industry itself, so that it became necessary to adopt measures to correct some

of the evils of unregulated competitive development of oil resources.

The measures adopted by the various states to prevent some of the physical and economic waste of competitive development took the form of conservation statutes. These conservation statutes were designed to regulate the drilling of wells and the production of oil in such manner as to prevent physical waste. The conservation laws of the various states show wide differences with respect to detail but, in general, their purpose is to prevent physical waste. In order to do this, regulations are laid down with regard to the distance between wells, with regard to the nature of the equipment to be used in producing the oil, and with regard to the allowable production. Regulations of this character are primarily technical considerations designed to promote efficient production and to increase the recovery of crude from the reservoir. Such regulations in themselves might result in curtailing production considerably below the requirements of this country, or they might, on the other hand, result in a production larger than the market requirements, depending upon the relationship between the total reserve and the market demand. During the earlier period of development in the industry, when the reserves were frequently so small that it was difficult to meet the demand even with inefficient producing rates, there would naturally have been opposition from both the producer and the public to any suggestion of a curtailment of the supply. However, as the industry discovered additional reserves and the productive capacity became larger it was possible to develop a program of conservation which would take into account physical waste and also, in some cases, market demand.

The situation of the industry at present is that of having a productive capacity far in excess of the immediate demand, in spite of the fact that the known supply will last only 14 years. The State of Texas alone could easily supply the entire domestic demand for crude of about 3,500,000 barrels per day, although its production in the recent past has been between 1,350,000 and 1,450,000 barrels per day. Other oil-producing states are also in a position to produce much more than the amount which they are currently producing, although not to the same extent as Texas. There exists, therefore, a considerable excess capacity to produce immediately in relation to the present demand. However, if each state were to produce as much as possible, there would result a great waste of our petroleum resources, for the amount of oil which would be recovered ultimately would be reduced as a result of the loss of gas pressure, encroachment of water, and other operating difficulties which would occur. In other words, the industry can produce more than the present demand but only at the cost of

some waste of resources. It is probably true that if all fields were operated at their most efficient producing rate, the production would not be sufficient to meet the demand. As it is at present, some states produce less than the most efficient rate will permit, while others produce much more than they should. The problem of allocation of production between states and between fields within a state is one which should be determined by efficient engineering practices rather than by political expediency. It is one of the difficult problems facing the industry, but one to which the statistical and engineering data would probably give a relatively accurate answer if used fairly and impartially.

With the existence of what appears to be excess capacity in the oil industry, the question may be raised whether the industry is justified in continuing its search for additional reserves and, thereby, increasing the amount of excess capacity. The industry believes that in view of the relatively short number of years' supply of its known reserves it should continue an active search for additional reserves. The ideal situation would be one in which reserves could be discovered and kept idle until the day when they will be required to meet the demand. However, in the search for oil it is necessary to drill wells and it is customary to develop the pools found within a short time of their discovery, for that is the way in which the discoverer is rewarded for his effort in finding the oil. Naturally under present conditions the industry should attempt to slow down the rate of drilling in new pools. This can be done by encouraging wide spacing of wells in all future developments. It has already been pointed out that close spacing of wells has resulted in an enormous economic waste of capital in the past. If 10 wells are drilled on a 10-acre tract where one well would be sufficient to produce all of the oil underneath that tract, then 9 of the said wells will involve a waste of capital investment from an economic standpoint. The wells may be profitable to their owners, but they are not contributing to the welfare of society for they add nothing to the resources available for consumption.

The extent to which wide spacing can be encouraged is dependent to a considerable degree upon the method of allocating production between fields and between leases. A method of allocating production which distributes the allowable entirely on a per well basis inevitably encourages the drilling of a large number of excess wells. Allowables may also be allocated on a number of other factors, such as oil in place, acres per well, or well potential. The present proration orders in most states involve various combinations of the different factors by which allowable may be regulated. It would seem clear that the ideal formula for allocating production would be one which made production pro-

portional to the recoverable oil in place. This would do justice as between the different property owners and would also encourage wide spacing. In order to permit the full development of this rule the pooling of small properties should be permitted so that the owner of a small tract will not be forced to drill a well on his property in order to recover the oil which may properly be considered as belonging to him. Such measures to permit pooling of properties have been adopted in some states, and laws of this nature may even extend to a requirement that such pooling be done wherever necessary to prevent physical waste.

In order to provide for the proper economic development of petroleum resources it seems necessary: (1) that the industry should conserve its resources because of the public interest, and (2) that the industry should stop unnecessary drilling. The first measure is necessary in the public interest in order to provide a supply of oil at low cost as long as possible. The second measure is necessary in order to prevent the industry from needless investment of capital which will be a burden both to the industry and to the consuming public which will be expected to pay for the investment. Some progress has been made during recent years in these directions and there are signs that regulation in the future will tend increasingly toward bringing about wider spacing and more efficient methods of production.

The discussion thus far has been confined to the problems in the production of oil, which we consider the primary phase of the petroleum industry. Before turning to a consideration of the manufacturing of products from crude oil, it may be well to restate in summary fashion the problem of conservation. It can be said briefly that: (1) petroleum is an exceedingly important source of energy in our mechanized economy; (2) it is a product for which we can find substitutes only at higher cost; (3) the known supply of it is extremely limited; and (4) it is necessary to conserve petroleum by efficient methods of production and use in order that the supply may be made to last as long as possible and the cost may be kept from increasing unduly.

The efficient production of crude oil is naturally the basic requirement for sound economic operation, but even if this were achieved there would still be opportunity for waste unless the industry made efficient use of the oil produced. In other words, the manufacture of products from crude oil must be technically efficient, and must also adjust supply and demand. This brings us to a consideration of the refinery branch of the petroleum industry. One of the chief characteristics of the refining industry is the production of numerous products jointly from one raw material. There are literally hundreds of products

which have their basis in the refining of petroleum, including such diverse things as insecticides, cosmetics, and medicines, but the products of a refinery which are of principal interest to the ultimate consumer are gasoline, kerosene, heating oils, fuel oils, and lubricants. These products are produced in varying proportions by the refining of crude oil. Some crude oils are better suited to the production of gasoline of a high octane rate, whereas others are better adapted to the production of lubricating oils. The industry must attempt to produce all of these various products in such proportion as to meet the demand. In the earlier development of the petroleum industry the principal demand was for kerosene, the other products being of almost no use at that time. Later in the history of the industry the principal demand shifted to fuel oils for industrial uses. The development of the automobile created an important market for gasoline so that in the period since the end of the World War gasoline has become a principal product. The industry has been able to adapt itself to these changes in demand by improvements in technique which made it possible to raise the yield of the products in greatest demand and lower the yield of other products. At present the yields of the principal products are approximately as follows: gasoline, 44.1%; kerosene, 5.6%; gas-oil, 13.0%; fuel oil, 25.3%; lubricants, 2.7%. There are times when a shift in the relationship of the demand for the various products calls for an adjustment in the yields. The increasing demand for gas and heating oils within recent years is an illustration of such change. Technological progress in the development of the cracking processes helped the industry to adjust itself to changes in demand in the past, and the development of the new Houdry process will permit even more flexibility in adjusting yields to changing demands.

The demand for the various petroleum products is relatively inelastic. We mean by this statement that price changes within the customary range do not materially affect the amount consumed. The consumption of gasoline, and particularly of fuel oil is influenced more by the national income and the level of industrial activity than by variations in the prices of these products. Domestic gasoline demand in 1938 was practically unchanged from 1937, although gasoline prices tended to be lower than in 1937. Fuel oil demand in 1938 was far below that of 1937 even though fuel oil prices were much lower in 1938. This was due to the sharp recession which occurred in industrial activity between September, 1937, and June, 1938. With the improvement in industrial production which occurred in the last half of 1938 the demand for fuel oil showed a rapid recovery and prices for this product began to show corresponding improvement. The inelastic de-

mand for petroleum products is a benefit in one sense in that it may contribute to stability in the industry, but it may be a disadvantage in another way in that price adjustments do not readily restore equilibrium after the industry has reached an unbalanced situation between demand and supply.

There are many other economic aspects of the industry which we might consider besides those involved in the production and refining branches of the business. The transportation and marketing phases of the industry might be analyzed to see what their problems are and whether they are functioning efficiently. With regard to the transportation of crude oil and products, it is well known that the industry has developed highly specialized systems of its own, pipe lines and tankers, which have helped to reduce the cost of transportation for crude and refined products far below what it would be by railroads. The pipe lines are closely regulated by the Interstate Commerce Commission as to rates, accounting methods, and many other practices. It seems safe to say that the transportation system of the petroleum industry is performing a good job at a low cost. It is unfortunate that this same statement can not be made with regard to the marketing branch of the industry. While the retail outlets of the industry have provided many services at great convenience for the motorists, the competitive situation has resulted in a number of service stations which is probably in excess of the amount needed to do an efficient job of retailing. It is estimated that there are 226,000 service stations and 182,000 secondary outlets for gasoline, making a total of 408,000 gasoline outlets for 29,500,000 automobiles, or one outlet for every 72 automobiles. The marketing function could probably be done more efficiently with a smaller number of units, but the motorists might not be pleased if this efficiency interfered with the convenience of the numerous stations to which he has become accustomed.

One other economic aspect of the industry which should be mentioned is the character of the business unit in the petroleum industry. The typical unit in the industry is the integrated corporation carrying on several phases of the business. Most of the important units in the industry engage in the production, transportation, refining, and marketing of crude and products. These units are integrated to a very high degree, frequently handling their products through their own transportation and distribution systems until the time of delivery to the ultimate consumer at a retail gasoline station. There are certain advantages in the integration of the various processes of the petroleum industry which tend to encourage the development of large units engaged in all of the branches of the industry. A producer may find it

difficult to market his crude if he does not have some connections with a transportation system or with a refinery. If the producer has a transportation system and a refinery, then he is free of a market problem up to the point of the disposition of his refined products in either the wholesale or the retail markets. The refiners find it advantageous to have retail distributing systems which insure them a fairly steady outlet for a portion of their products. Similarly the retail distributors may find an advantage in having an assured source of a uniform product.

The large investment required in the production, transportation and refining branches of the petroleum industry is a significant feature which has helped shape the character of the business units in this field. It is estimated that the investment of the petroleum industry amounts to $47,500 per worker in the production division, $40,600 per worker in pipe lines, and $38,700 per worker in refining. The expensive nature of much of the equipment used in the oil industry requires units of considerable size to utilize them advantageously and at low cost per unit. The oil industry is typically a modern mass production industry engaged in handling a tremendous volume of raw materials and finished products, and as such it finds the usual advantages in large scale operations.

In spite of the fact that the large scale units in the petroleum industry carry on a major portion of the business there are, nevertheless, thousands of individual operators and partnerships engaged in the various branches of the business. The existence of these large and small units has given rise to the loose reference in common practice to the so-called "majors" and "independents." There are, no doubt, some cases in which the majority of small operators find their interests opposed to some extent to the interests of the majority of large operators. However, it is also true that there are many cases in which the interests of the so-called "majors" are divided and frequently the interests of some "independents" may coincide with that of some "majors" while other "independents" find themselves aligned with a different group of "majors" as far as their interest is concerned. The existence of large units has not acted to stifle competition, but on the contrary, has resulted in very keen competition between the large units themselves. In this connection it is interesting to note that a recent book by a well known economist, Walton Hamilton, on *Price and Price Policies* discusses the petroleum industry under the heading "Gasoline: The Competition of Big Business."

Against this background of the economic problems of the industry, it is interesting to note that there is a wealth of statistical information

available on the industry to assist in the clarification of its problems. The information available on the demand, supply, and stocks of the petroleum industry is probably as complete as is available for any other industry, and far more complete than on most industries. The American Petroleum Institute issues weekly bulletins which estimate crude production, crude runs to stills, gasoline production, stocks of gasoline, gas-oil and fuel oil, and imports of petroleum. The Bureau of Mines issues a weekly bulletin of stocks of crude oil by grade or origin. The Bureau of Mines also issues a monthly survey of the industry, which is a comprehensive record of almost every conceivable phase of the industry. These sources plus the reports of various state commissions, and the statistics compiled by the trade journals, give a complete record of the developments within the industry shortly after they occur. In addition, the Bureau of Mines issues a monthly forecast of the demand for gasoline and crude, and the distribution of that demand by states. There have been numerous special studies, such as the Petroleum Administrative Board's "Cost of Producing Oil," the Bureau of Mines' "Survey of Crude Oil in Storage, 1936–1937," and various estimates of crude reserves, which have added to the basic statistics available on the industry. There is a wealth of statistical information on the industry, and much of it is extremely useful in determining the course of the industry and in studying special problems on which wide differences of opinion frequently occur unless resort is made to statistical data.

GEOPHYSICAL INTERPRETATION[1]

REPORT OF HOUSTON GEOLOGICAL SOCIETY STUDY GROUP[2]

M. H. BILLINGS[3] *ET AL.*

The object of this study was to arrive at an estimate of the comparative values of the different types of geophysical methods commonly used in locating subsurface structural uplift, and in general, to gain a better acquaintance with the geophysical methods in use to-day.

The group studied the general principles, the applications, the determination of results, and the reliability or accuracy of the results of each type.

[1] Manuscript received, December 12, 1939.

[2] Members of group: M. H. Billings, leader, O. B. Banks, V. A. Brill, E. W. Brucks, W. F. Calohan, Bernie Haugen, J. W. Hoover, F. H. McGowan, G. D. Mitchell, F. W. Mueller, Sam E. Simms, J. A. Wheeler.

[3] Tarlac-Tarlac, Manila, Philippines.

In the course of this study, seven meetings were held. At each meeting a different one of the principal geophysical methods was discussed by some worker in geophysics who was well versed and experienced in the type discussed.

In this manner, the group had the opportunity of studying the magnetometer, the torsion balance and gravity meter, the refraction seismograph, the reflection seismograph, electrical prospecting (Eltran), and soil analysis (Subterrex).

The group endeavored to evaluate these different methods. By way of comparison, the magnetometer, the gravity meter, electrical prospecting, and soil analysis are regarded as reconnaissance methods for rapid prospecting, and not especially suitable for the detail work required before locating a test well. The torsion balance is regarded both as a reconnaissance and as a detailing instrument, but the gravity meter has largely replaced the torsion balance during the past five years. The refraction seismograph was also used both for reconnaissance and for detail work, but this method is very expensive in operation compared with the other reconnaissance types, and the use of the refraction seismograph is very much restricted at the present time. These methods, as mentioned above, have probably discovered the greater number of such geophysical anomalies as turned out to be related to true subsurface uplifts.

However, it is conceded that the reflection seismograph is far superior to any of the above-named methods for detailing an area, and for depth estimates on certain horizons such as massive limestones, massive sands, and igneous rock, but in the case of depth determinations on massive rock salt in the salt-dome region, the refraction seismograph may be as accurate as the reflection type.

The reflection seismograph is also regarded as being more efficient than any other geophysical instrument in correcting or lessening the asymmetry factor in deep-seated anomalies, and lends a measure of certainty to the theory that the subsurface uplift directly underlies the prospect as mapped.

Further improvements in reflection-seismograph instruments are anticipated, by which this instrument may identify deep-seated fault displacements with greater accuracy than was heretofore possible; and this may result in a campaign to re-shoot large areas of prospective oil lands that have not shown favorable geophysical anomalies under past methods.

SEDIMENTATION[1]

REPORT OF HOUSTON GEOLOGICAL SOCIETY STUDY GROUP[2]

MICHEL T. HALBOUTY[3] *ET AL.*

The members of the Sedimentation Group of the Houston Geological Society were cognizant of the fact that a study of sedimentation covered a large and variable field and that as the interest centered on the sedimentary cycles and factors that controlled the deposition of the Gulf Coast sediments, it was decided at the first meeting of the group to review the general aspects of sedimentation and apply factors controlling the basic principles of sedimentation to conditions in the Gulf Coast of Texas and Louisiana. A study of the various processes of sedimentation was conducted for the first six weeks. These processes included source of the sediments, the production of sediments, transportation and deposition of sediments, conditions modifying sedimentary processes, various kinds of sediments, structural character of sediments and the environments controlling deposition of sediments. After reviewing these fundamental processes of sedimentation, a detailed study was conducted in which the sedimentary periods of the Texas and Louisiana Gulf Coast were briefly reviewed. The detailed study began with the events leading up to and the processes involved in the deposition of the Midway formation of lower Eocene age. Each subsequent formation was then taken and similarly studied through the Beaumont clays of late Pleistocene age. Under each formation, the following topics were discussed.

A. Source of sediments for all formations
   1. Kind of parent rocks
   2. Mode of transportation
   3. Character of final formation
      a. Limestone
      b. Shales
      c. Sands
      d. Marl

B. Transgressions and regressions of seas
   1. Effect of transgression on deposition of sediments
      a. Type of material deposited in various areas during movement of the sea. ("Various areas" included both marine and continental phases or what was happening on land during marine deposition.)
      b. Effect of transgression on previously deposited "older" formations
   2. Effect of regression on deposition of sediments

[1] Manuscript received, December 12, 1939. Presented in greater detail by Michel T. Halbouty at the meeting of the Houston Geological Society, February 9, 1939.

[2] Members of group: Michel T. Halbouty, leader, Douglas Bell, O. L. Brace, W. A. Clark, Eugene L. Earl, C. E. Edgerton, Leo Horvitz, R. J. Metcalf, Carl Richardson.

[3] Merit Oil Company, 803 Shell Building, Houston, Texas.

a. Type of material deposited in various areas during movement of the sea. ("Various areas" included both marine and continental phases or what was happening on land during marine deposition.)
b. Effect of regression on previously deposited "older" formations

3. Transition zones
a. Type of sediments in transition zones
b. Type of micro-fauna
c. Importance of "transition zones"
d. Extent of transition zones updip and downdip

C. Possible presence of old shore lines, barriers, lagoons, swamps, *et cetera*
(Geological deductions were employed under this heading in determining how various conditions could form. Rough sketches were made to outline the positions of various old seas and their corresponding shore lines, swamps, lagoons, and barriers.)

D. Correlation of sands within a formation
(Petrographic, electric logs, mechanical analyses were discussed in order of their respective importance.)

E. The relative area-positions of sand or shale horizons which pinch out updip without structural evidences being present and the requisite conditions that must be present to give these pinch-outs and how these requisites may be detected. Various examples were used

F. Possible means of determining the presence of stratigraphic traps by employing known Gulf Coast sedimentary factors

G. Application of known sedimentary factors to Gulf Coast formations; that is, to the physical characteristics of the formations
1. Effect of these factors on porosity and permeability
2. Effect of these factors on electric logs
3. Factors causing presence of connate waters in oil sands

H. The application of isopach maps and how the maps may be used in correlating any sedimentary factor that might be present in any particular formation

I. Laboratory technique was discussed: employing the use of (1) chemical analysis of cores, (2) mineral studies of sands, (3) mechanical analysis of sands

This outline of the study group would take years to complete with every particular phase worked out in detail. In the three months that the group studied the phases of sedimentation and applied them to the Texas-Louisiana Gulf Coast, only the high-lights of the factors involving deposition were taken into consideration. One can readily observe that it would be an impossible task to complete a detailed study in sedimentation of the area involved in a period of three months.

The members of the Sedimentation Group feel that considerable knowledge was gained by the study due to the discussions that were inevitable in a group of this kind. Every member of the group highly recommended the continuation of this work and felt that some sort of appropriation should be made for research study to continue over a period of years. The group feels that a practical study of sedimentation for a restricted area will uncover many geological facts which will eventually prove to be economically important to the oil industry as well as academically.

It is not the purpose of this report to analyze the result of the work that was done, but to point out the form of study that was conducted, the interest that was shown, and the importance of the continuation of such a study.

REFERENCES

Numerous references were used by the members of the Group. A few are the following.

Wm. H. Twenhofel, *Treatise on Sedimentation.*
R. A. Daly, *Igneous Rocks and the Depths of the Earth.*
C. K. Leith, *Structural Geology.*
"Research in Sedimentation, 1924," A Report of the Committee on Sedimentation, W. H. Twenhofel, *Chairman*, issued by the National Research Council, April 25, 1925.
"Report of the Committee on Sedimentation, 1928–1929," W. H. Twenhofel, *Chairman*, issued by the National Research Council, 1930.
———, 1929–1930 (1931).
———, 1930–1932 (1932).
———, 1932–1934, A. C. Trowbridge, *Chairman*, issued by the National Research Council, 1935.
———, 1935–1936, P. D. Trask, *Chairman*, issued by the National Research Council, September, 1936.
———, 1936–1937 (May, 1937).
———, 1937–1938 (April, 1938).
"Report of the Committee on the Measurement of Geologic Time, 1937–1938," Alfred C. Lane, *Chairman*, issued by the National Research Council, April, 1938.

Various scientific papers by the following authors, involving sedimentation, were used: M. I. Goldman, Henry B. Milner, A. C. Trowbridge, W. H. Twenhofel, C. K. Wentworth, F. J. Pettijohn, Carl B. Brown, R. D. Reed, T. Wayland Vaughan, W. A. Tarr, David White, John T. Lonsdale, J. A. Udden and E. H. Sellards.

NOTES ON THE FRIO[1]

REPORT OF HOUSTON GEOLOGICAL SOCIETY STUDY GROUP

M. C. ISRAELSKY[2]

The following notes review the more pertinent papers dealing with the term Frio, and attempt to show the various uses of the term as interpreted by the reviewer. In some of the areas the reviewer is without first-hand information and corrections will be welcomed.

Though Hanna and Gravell[3] have pointed out that the marine wedge commonly known as the Middle Marine Oligocene is not of that age, and the reviewer believes the name should be dropped and foraminiferal zonal names used in its place, it is here used parenthetically, due to its prevalence in the papers considered.

[1] Manuscript received, December 12, 1939.

[2] Union Producing Company, Houston, Texas.

[3] Hanna and Gravell, *Jour. Paleontology*, Vol. 11, No. 6 (1937), pp. 60–65.

1894. DUMBLE, E. T., "The Cenozoic Deposits of Texas," *Jour. Geology*, Vol. 2, pp. 554–55.

ORIGINAL USAGE. p. 554—"The Fayette passes upward into a series of gypseous clays with sand and sandrock, differing greatly lithologically from the underlying beds. This subdivision is therefore proposed for them.

"The clays are dark colored, greenish gray, red or blue, usually massive, with quantities of gypsum and with calcareous concretions arranged in lines, giving them a stratified appearance. The sandy clays are laminated and bedded, green, red or blue in color, and interbedded with brown and green sandstone, which is concretionary and, in places, highly indurated. Brown sands overlie these, and are followed by laminated chocolate clays containing concretions of crystalline limestone with manganese dendritions. These clays weather white, as at the mouth of the Frio.

"Typical exposures: Between Weedy creek and Oakville on Atascosa and Frio rivers, and on the Nueces south of Tilden. . . ."

Dumble very apparently included beds classified on present geologic map as Frio and Catahoula (Gueydan). Probably some Jackson also included.

1903. DUMBLE, E. T., "Geology of Southwestern Texas," *Trans. Amer. Inst. Min. Met. Eng.*, Vol. 33, pp. 953–56.

Map (Fig. 1) and sections (Fig. 2) show Frio used as in 1894 paper. Numerous details of outcrop.

1903. HAYES, C. W., and KENNEDY, W. "Oil Fields of the Texas-Louisiana Gulf Coastal Plain," *U. S. Geol. Survey Bull. 212*, pp. 22–23, 30–66.

A map (Pl. 1) shows the Frio generally covering the same outcrop as shown by Frio-Catahoula of present maps and runs into Louisiana.

1911. DUMBLE, E. T., "The Middle and Upper Eocene of Texas," *Trans. Texas Acad. Science*, Vol. 11, p. 51.

General remarks only.

1923. BAILEY, T. L., "The Geology and Natural Resources of Colorado County," *Univ. Texas Bull. 2333*, pp. 44–48.

Uses Frio in a limited sense. Reports it in wells. Later wells show interpretation to be incorrect.

1923. TROWBRIDGE, A. C., "A Geologic Reconnaissance in the Gulf Coastal Plain of Texas, near the Rio Grande," *U. S. Geol. Survey Prof. Paper 131*, pp. 97–98.

Map and text show Dumble usage of term. *Ostrea georgiana* and silicified wood found.

1924. DUMBLE, E. T., "A Revision of the Texas Tertiary Section with Special Reference to the Oil-Well Geology of the Coast Region," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 8, p. 434.

Frio continued in its original usage. Volcanic nature of some beds recognized.

1924. DEUSSEN, ALEXANDER, "Geology of the Coastal Plain of Texas West of Brazos River," *U. S. Geol. Survey Prof. Paper 126*, pp. 91–95.

Uses Frio in Dumble's sense. Recognizes probable equivalence of upper Frio (Dumble) with the Catahoula on the east.

1926. BAILEY, T. L., "The Gueydan, a New Middle Tertiary Formation from the Southwestern Coastal Plain of Texas," *Univ. Texas Bull. 2645*, pp. 44–52.

The varying limits of Frio as used in earlier papers are pointed out. "Frio" is restricted to those beds which consist "almost entirely of very soft and plastic, gypsiferous, creamy-green to light grayish-green and purplish-pink clays or variegated pink and green clays." "One of the best exposures of the upper Frio bed is found in a cut along the San Antonio, Uvalde and Gulf Railway, 1 mi. n.w. of Fant City, Live Oak County."

Bailey's Frio is that of the present geologic map of Texas. The upper portion or ash beds of Dumble's Frio is called Gueydan and the essential equivalence with the Catahoula, by lateral gradation, is recognized. From the base upward, the Gueydan was subdivided into the Fant, Soledad, and Chusa.

1931. GARDNER, JULIA, and TROWBRIDGE, A. C., "Yeager Clay, South Texas" (with discussion, pp. 967–70), *Bull. Amer. Assoc. Petrol. Geol.* Vol. 15, pp. 470; 967–70.

Suggest Yeager to be used in same sense as Bailey's Frio. Frio used in same sense as Gueydan of Bailey.

1931. FINCH, E. H., and others, "Yeager Clay, South Texas," *ibid.*, Vol. 15, pp. 967–70.

Defends Bailey's usage. Confirms Catahoula equivalence of the Gueydan, contains the first noted statement that in the subsurface the Catahoula is separated from the Frio by fossiliferous "Middle Marine Oligocene." The Frio considered Vicksburg.

1931. BRACE, O. L., "Factors Governing Accumulation of Oil and Gas in Mirando and Pettus Districts, Gulf Coastal Texas, and Their Application to Other Areas," *ibid.*, Vol. 15, pp. 761–62.

Frio used in old sense. Cole sand placed in Frio.

1932. LAHEE, F. H., "Frio Clay, South Texas," *ibid.*, Vol. 16, pp. 101–02.

Reports the acceptance of the restricted "Frio" of Bailey by the U.S.G.S.

1932. TROWBRIDGE, A. C., "The Tertiary and Quaternary Geology of the Lower Rio Grande Region, Texas," *U. S. Geol. Survey Bull. 837*, pp. 156–65.

Accepts Bailey's usage of Frio. Calls Gueydan, Catahoula Tuff.

1932. BAILEY, T. L., "Frio Clay, South Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16, pp. 259–60.

Defends restriction of Frio; accepts Catahoula Tuff for Gueydan.

1932. COOK, C. E., "Areal Geology of the Catahoula Formation in Gonzales and Karnes Counties," *Univ. Texas thesis*, quoted in *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, pp. 530–32.

Summarizes change in nomenclatorial significance as applied to the Catahoula.

1932. PLUMMER, F. B., "The Geology of Texas, Vol. 1: Stratigraphy," *Univ. Texas Bull. 3232*, pp. 700–.

Gueydan used as group name, including from top to bottom: Catahoula, Unnamed "Middle Oligocene" strata, Frio, Vicksburg. On the outcrop Bailey's Frio used. In the subsurface Ellisor's usage (1933) is anticipated.

1933. ELLISOR, ALVA C., "Jackson Group of Formations in Texas with Notes on Frio and Vicksburg," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, pp. 1293–1350; *Geology of Gulf Coast Oil Fields*, pp. 470–527.

"The name Frio is here used to designate those clays which occur in wells between the Middle Oligocene and the Vicksburg. . . . These clays occur on the surface unconformably below the Catahoula 'rice sands' or Soledad, and rest unconformably on the Whitsett . . . includes the Fant member of Bailey's Gueydan and his Frio."

1933. McCarter, W. B., and O'Bannon, P. H., "Sugarland Oil Field, Fort Bend County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, pp. 1362–86 (pp. 1367–77); *Geology of Gulf Coast Oil Fields*, pp. 709–33 (pp. 715, 724).

Frio used in Ellisor's sense. Vicksburg questionable.

1933. Teas, L. P., and Miller, C. R., "Raccoon Bend Oil Field, Austin County, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 17, p. 1465.

Apparently regards the "Frio" as a vertical and lateral variation of the Vicksburg. Use of "Frio" seems to be close to that of Bailey.

1934. Deussen, Alexander, "Oil-Producing Horizons of Gulf Coast in Texas and Louisiana," *ibid.*, Vol. 18, pp. 500–18.

Uses "Frio" in Ellisor's sense.

1934. Getzendaner, A. E., "McFaddin-O'Conner, Greta, Fox, Refugio, White Point and Saxet Fields, Texas," *ibid.*, Vol. 18, pp. 519–30.

Does not use term "Frio."

1934. Goldston, W. L., and Stevens, G. D., "Esperson Dome, Liberty County, Texas," *ibid.*, Vol. 18, pp. 1632–54.

Appears to have used "Frio" in Ellisor's sense.

1935. Brucks, E. W., "Buckeye Field, Matagorda County, Texas," *ibid.*, Vol. 19, pp. 378–400 (pp. 391–93); *Geology of Gulf Coast Oil Fields*, pp. 734–56 (pp. 747–49).

Lower Catahoula used as equivalent to Ellisor's "Frio."

1935. Stamey, R. A. and others, "Greta Oil Field, Refugio County, Texas," *ibid.*, Vol. 19, pp. 544–59; *Geology of Gulf Coast Oil Fields*, pp. 648–63.

Approximates Ellisor's usage of "Frio."

1935. Halbouty, M. T., "Geology and Geophysics of Southeast Flank of Jennings Dome, Acadia Parish, Louisiana, with Special Reference to Overhang," *ibid.*, Vol. 19, pp. 1308–29.

Uses Vicksburg in Ellisor's sense of the "Frio." Marine phases probably belong in Garrett's Hackberry. (Garrett, 1938, *Jour. Paleontology*, Vol. 12, No. 4, pp. 399–17.)

1935. Burford, Selwyn O., "Structural Features of Brenham Salt Dome, Washington and Austin Counties, Texas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, pp. 1330–38.

Shows "Frio" in cross sections but does not discuss in text. Usage not clear.

1935. Teas, L. P., "Natural Gas of Gulf Coast Salt-Dome Area," *Geology of Natural Gas* (Amer. Assoc. Petrol. Geol.), pp. 683–740. (Frio: Manvel dome, p. 729; Boling, p. 702; Iowa field, p. 732; Orchard field, p. 710; Barbers Hill, p. 707; Sugarland, p. 713.)

Uses Frio in Ellisor's sense in column.

1936. Deussen, Alexander, and Andrau, E. W. K., "Orange, Texas, Oil Field," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 20, No. 5, pp. 531–59.

Vicksburg used for equivalent of Ellisor's "Frio." Opinion expressed by them that Marginulina-Frio section is missing. The marine beds below the Heterostegina zone belong to Garrett's Hackberry phase.

1936. HALBOUTY, MICHEL T., "Geology and Geophysics Showing Overhang of High Island Dome, Galveston County, Texas," *ibid.*, Vol. 20, No. 5, pp. 560–611.

Apparently used Vicksburg as equivalent to Ellisor's "Frio." Fossiliferous zone probably pertains to Hackberry phase.

1936. MICHAUX, F. W., JR., and BUCK, E. O., "Conroe Oil Field, Montgomery County, Texas," *ibid.*, Vol. 20, No. 6, pp. 736–79.

Use Catahoula-Frio without differentiation. Remark on "rice" sands near base.

1937. THOMPSON, WALLACE C., "Geologic Sections in Texas and Adjoining States," *ibid.*, Vol. 21, pp. 1083–87, section B.

Frio is used in Ellisor's sense when "Middle Marine Oligocene" is present, but not recognized updip where equivalent beds are classed as Catahoula. Sections C and E. Uses "Frio" in Ellisor's sense, both down and updip.

1937. COOPER, HERSCHEL H., "Occurrence and Accumulation of Oil in Laredo District, Texas," *ibid.*, Vol. 21, pp. 1422–38.

Uses Frio in Bailey's sense, uses Catahoula Tuff for Bailey's Gueydan.

1938. MARTYN, PHIL F., "Geology of the Refugio Oil and Gas Field, Refugio County, Texas," *ibid.*, Vol. 22, pp. 1184–1216.

Restricts Catahoula to beds above marine zone ("middle Marine Oligocene") and Frio to beds below the Marine zone. Considers Vicksburg sand to be present. The reviewer does not consider this correlation to be demonstrated.

1939. MEYER, WILLIS G., "Stratigraphy and Historical Geology of Gulf Coastal Plain in Vicinity of Harris County, Texas," *ibid.*, Vol. 23, No. 2, pp. 145–211.

On p. 175, Meyer gave alternate correlations of the outcrop Catahoula with downdip beds; (A) showing the marine wedge in the Catahoula, and (B) the Catahoula overlapping the marine wedge and the "Frio." He favors the latter.

The paper is very convincingly written so attention should be called to the construction of his cross section. Wells have been projected as much as forty miles into the section. In a territory with the rapid lithologic changes here present this is hardly good practice.

It is the reviewer's opinion that the Chita member of the outcrop Catahoula passes under the marine zones, rather than overlying them.

In summation, there are three established usages of the term Frio in the literature best illustrated by the following.

1. The original of Dumble (1894) included all beds above the Fayette and below the Oakville. The upper limit of his Fayette is that shown on the present map of Texas as Jackson, the base of the Oakville as shown at present. His Frio includes the Frio and Catahoula as shown on the present map.

2. Bailey's (1926) usage restricted the term to the essentially nonvolcanic beds, and he applied the name Gueydan to the overlying volcanic and reworked volcanic sediments. His Frio is that of the present map of Texas.

3. Ellisor (1932) redefined the Frio to include the restricted Frio of Bailey, and also the Fant member of his Gueydan and it was assumed that the Soledad conglomerate passes downdip into the coarse sands underlying the "Middle Marine Oligocene." The physical continuity of these beds has not been demonstrated, although it is interesting to speculate that a seaward tilting permitted the simultaneous invasion of the "Middle Marine Oligocene" and the descent of the Soledad conglomerates. There may well be a connection, but at this writing it seems unlikely a tie-line may be drawn.

Neither Dumble's nor Ellisor's Frio is a natural unit, as beds both above and below an unconformity are included. Bailey pointed out that his Gueydan rested first on his Frio, then on successively older members of the Fayette (Jackson of present map). This is confirmed by others, for instance David Perry Olcott, Phil F. Martyn, and Stuart Mossom (verbal communications).

By elimination this leaves Bailey's Frio as the only natural unit.

Justice is probably not accorded Dumble in restricting his name to so minor a constituent of its original application, but as the U. S. Geological Survey and the then San Antonio Geological Society agreed on Bailey's modification and it is so shown on the present map of Texas, future confusion will be avoided if it is allowed to remain in that sense a mappable surface unit.

The exact correlation of the Frio (Bailey) remains in doubt, some believing it to be the updip equivalent of large sand bodies downdip called Vicksburg. While at this time no strenuous criticism can be made of this correlation, it seems just as logical to show the Frio (Bailey) as overlapped by the allegedly Vicksburg sand bodies, in southwestern Texas, which *may* belong in the Catahoula.

Howe[4] very strongly suggested the equivalence of the "Middle Marine Oligocene" to a part of the Catahoula. In a still unpublished paper, Alexander[5] in his portion of it, convincingly showed Catahoula *above* and *below* the "Middle Marine Oligocene."

For convenience we may, when the "Middle Marine Oligocene" is present, use the names Upper Catahoula, "Middle Marine Oligocene," or "Marine Catahoula," and Lower Catahoula, bearing in mind the Upper and Lower Catahoula will vary according to the development of the "Middle Marine Oligocene" or Marine Catahoula.

[4] Henry V. Howe, "Review of Tertiary Stratigraphy of Louisiana," ***Bull. Amer. Assoc. Petrol. Geol.***, Vol. 17 (1933), pp. 635–43.

[5] R. T. Hazzard, A. M. Lloyd and C. I. Alexander, "North-South Cross Section, Arkansas to the Gulf of Mexico," read by title before the Association at New Orleans, March, 1938. Alexander's part was given before the Houston and other geological societies.

Where the Marine phase is poorly developed (updip) we simply recognize Catahoula (undifferentiated).

At the same time the question still exists of whether or not the Oakville of southwestern Texas is represented in the Catahoula of Louisiana. Respected opinion is found on both sides of the fence.

Also the wedge of sandy beds on the Refugio-Agua Dulce "trend" variously referred to as Frio equivalent or Vicksburg is still not conclusively placed.

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REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library and available to lend to members and associates.

CENTRAL AMERICAN POISONOUS SNAKES, BY C. PICADO T.

REVIEW BY WILLIAM W. PORTER II[1]
Los Angeles, California

Serpientes Venenosas de Costa Rica, by C. Picado T. An official publication of the Secretaría de Salubridad y Protección Social, San José, Costa Rica (1931). 220 pp., 58 photographs.

This book, published in 1931, is reviewed now because no previous review has appeared, and because the habitat of the snakes described is frequently explored by geologists. Copies may be consulted in the United States in a few scientific libraries, and at several universities; otherwise it is difficult to obtain.

The high mortality due to snakebite was responsible for the establishment in 1920 by the Board of Charity of Costa Rica, of a depository for antivenom serum from Brazil. Subsequently the need became apparent for a detailed study of the poisonous snakes of Costa Rica because of the widely variable types of poison, and the difficulties of selecting the proper serums to counteract the venoms of various snakes. This study was carried on by Dr. C. Picado T. and his assistants at the Laboratory of the Hospital de San Juan de Dios at San José, Costa Rica. The book mentions results up to 1931, but work is still going on, and although improvements in serum since publication are notable, only one rare new snake has been found.

Early studies indicated a fairly close similarity between many Costa Rican species and those of Brazil, and therefore the results obtained by Brazilian researchers were of great value.

About a dozen snakes are described. All are poisonous, but some are more deadly than others. Most of them have no English names.

Culebra del Mar [*Pelamis bicolor*] (Sea snake). Thin and less than a meter in length. Colored yellow and black. Poison same type as cobra but more purely neurotoxic. Inhabits Pacific waters only, near shore and in bays.

Corales [*Elaps fulvius, Micrurus fulvius, Elaps mipartitus*] (Coral snakes). Several are described. The poisonous varieties are similar to the North American corals, and have cobra type venom.

Cascabela Muda [*Lachesis muta*] (Bushmaster). Large vigorous muscular snakes with length exceeding 2 meters. Claw-like spine on the end of the tail. Is somewhat similar to a rattlesnake, but in many characteristics is decidedly different. Examples: lays eggs; has a peculiar and virulent venom. Is mainly nocturnal and is attracted by fires. Fangs 3 centimeters long have been measured.

Cascabela [*Crotalus terrificus*] (Rattlesnake). In general similar to U. S. rattlesnakes, but more deadly (by 8 times for rabbits). Mention is made of a green variety from Guatemala and an albino from Nicaragua. Poison a

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synthesis of two types: one attacks nerve centers; the other the blood and organs of the body. Large rattlesnakes carry enough of each to kill several men.

Terciopelo [*Bothrops atrox*] (Fer-de-lance). The terciopelo is by far man's greatest enemy among the Central American snakes. This is due to several characteristics: the deadliness of the venom; the large size often attained, and the large quantity of venom; high fecundity (the remarkable instance of 75 young in a single litter is mentioned, and the birth of 29 in the laboratory); and the adaptability to civilized surroundings. It does not retreat to the jungles as development progresses. The maximum quantity of venom extracted from a rattlesnake is 850 milligrams, and about 1,000 from a King cobra, but a Costa Rican terciopelo yielded 1,135 milligrams (enough to kill 100 men), and this same snake produced another 863 milligrams 25 days later. The length may exceed two meters, and fangs three centimeters long have been measured. At birth the young snake carries enough poison to kill a man. Experiments showed that the venom of the Costa Rican terciopelo was three and one-half times more toxic than venom of the same species in Brazil.

An instance is cited of two deaths from one bite. A man was bitten and his wife bathed the wound in hot water. Because of slight scratches on her hands she was fatally poisoned in spite of the dilution in water. The man died in two hours; the woman the next day. Speed of action of the poison seems to vary according to the tissues or blood conduits penetrated. A man stepped outside after a fight and was shortly found dead a few paces from the door. Murder was suspected, but autopsy showed death by a terciopelo, after whose bite the man took only a few steps. [This suggests stories of the "*cuatro nariz*," familiar to geologists who have worked in southern Mexico.] In most cases, however, the action of the poison is slow enough to permit serum treatment which almost always prevents serious consequences if administered in time.

Outstanding effects of the poison are to cause bleeding at the eyes, nose, gums, and kidneys. The blood corpuscles are dissolved and the blood coagulates. Swelling commences. Blood vessel walls and body tissues are destroyed. A peculiar mental effect is produced of dispair, desperation, and resignation to such an extent that one is frequently incapable of caring for himself. For this reason all members of a party should be instructed as to procedure and treatment.

Mano de Piedra [*Bothrops nummifera*]. The mano de piedra, called "Timbo" in Honduras, is named from its short fat shape similar to that of an Indian hand pestle of stone for grinding corn. Length is less than a meter, but it has the girth of a terciopelo twice as long. Is dark colored with inside of mouth completely white. Extremely active and strong. In attacking strikes several times in an instant, and continues striking. Has young in litters of five to 15, although 27 were born in the laboratory from an 85 centimeter female fed on beef.

Toboba chinga [*Bothrops lansbergi*]. A small snake about one-half meter in length, soil-colored with yellowish markings. Rather rare.

Tamagá [*Bothrops nasuta=B. brachystoma=B. ophryomegas*]. Rarely reaches one-half meter in length. Strictly nocturnal. Color cigarette ash gray to dark slate gray and blue-gray. Agile and jumps when surprised. A cannibal. A family of 18 ate each other until only one remained. Sometimes called

"chatilla" because of upturned nose. Called Tom Ego by English-speaking negroes of the Caribbean coast.

TREE-CLIMBING SNAKES

The tree snakes are also of the formidable *Bothrops* family, but have a prehensile tail, and bright colors, principally green.

Bocaracá (green), Oropel (yellow to orange) [*Bothrops schlegelii*]. Rarely 90 centimeters in length, and most variable in color: green, yellow, orange, brilliant emerald green with black stripes, blue-green and gray, sepia with green, etc. The oropel whose color varies from canary yellow to golden orange is believed to be a type of albino.

A striking effect of eyelashes is produced by spiny protuberances on the scales over the eyes. These snakes live much in trees where, simulating branches or vines, they coil ready for attack. Frequently found on the banana coast but range up to the plateau.

Víbora de Arbol [*Bothrops nigroviridis*]. Small (apparently less than a meter) green spotted snakes living in trees in forests ranging up to altitudes of 2,000 meters above sea level. Same family as the Guatemalan tree snakes of green with yellow mottling. Poison produces effects of paralysis and asphyxiation.

Culebra Lora [*Bothrops lateralis*]. A rather rare, bright green, small tree-living snake found occasionally in coffee plantations. Poison produces extreme local swelling out of all proportion to its actual effect.

Forty-two pages are devoted to discussion of venom which is of two general types: one affecting the nervous system, and one affecting body organisms.

Sea snake and coral poison is primarily neurotoxic and produces sharp pain and paralysis, although one variety of coral poison attacks the red corpuscles and coagulates the blood.

The *Bothrops* poison, although varying in detail, attacks the blood and tissues of the body. Several effects are: dissolution of blood corpuscles, particularly the red ones; coagulation of the blood (occasionally so rapid as to cause almost immediate death if a large amount of poison is injected into a major blood stream); agglutination of the corpuscles and leucocytes; destruction of cell tissue, glands, and blood vessels; destruction of albuminoids. These effects vary in degree and combination in different species. Terciopelo poison is 15 times more deadly to rabbits than an equal volume of toboba chinga poison. Various physical and chemical properties of poisons are discussed.

Geologists will be interested in learning the value of ticks. The troublesome tropical type, "garrapatas" " . . . are parasites on poisonous snakes. A few of these . . . on fixing themselves to a serpent, produce in it paralysis, . . . and death in a short time. These [garrapatas] carry on a control unsuspected by man, over the increase of serpents."

A chapter on the care and feeding of snakes in captivity will be of interest to those contemplating a poisonous snake collection.

Research in São Paulo, Brazil, at the Instituto Seroterápico de Butantan, is frequently referred to, and also mention is made of the more recent Antivenin Institute of America in the United States, and to the serpentarium at Tela, Honduras. Costa Rican experiments indicated the importance of re-

gional variations of poison, even of the same species, and led to the development of serums more effective against local venoms. A single serum was developed for all the poisons of Costa Rica. Although warning is given that this serum is only for snakes of the country, it is probably of great value in other parts of Central America, and should certainly be superior to usual remedies unless a specially developed substitute has been developed for local use. Anti-venom serum is supplied to the chiefs of police in the various provinces, and large ranches are required by law to keep a supply. A chief of police in one of the isolated Caribbean provinces told the writer he had treated 14 persons for terciopelo bite during 1938, and that all recovered. Serum is available at reasonable prices to those contemplating exploration.

A valuable antidote in the form of caution and respect will be gained by anyone visiting Dr. Picado's serpentarium and museum collection.

REPORT OF THE COMMITTEE ON SEDIMENTATION, 1938–1939, BY PARKER D. TRASK *ET AL.*

REVIEW BY E. W. GALLIHER[1]
Los Angeles, California

Report of the Committee on Sedimentation, 1938–1939. Parker D. Trask, chairman, National Research Council Division of Geology and Geography, Washington, D. C., April 29, 1939. Mimeographed, 102 pp. Price, $0.15 (postage).

Students of this country are fortunate in having prepared for them each year a fairly concise idea of what transpires in both domestic and foreign literature in the various fields of sedimentation. During the past three years Parker Trask has included in the volume published by the Committee summary reports of progress written by many authors. The topics discussed and summarized are either of special interest, or deserve special attention, or have suffered from lack of attention because the original articles were in foreign language periodicals not generally available.

In the latter group, in the 1938–1939 report, is a particularly meaty bibliography of recent Russian publications on sedimentation, prepared by P. D. Krynine. Of the thirty-seven papers annotated, the majority are studies of transportation, mineralogy, or petrography of sediments, with papers on petrology, paleogeography and genesis running a close second. Weathering and erosion, deposition, diagenesis and technique also are discussed in many articles.

To sedimentary petrologists, V. P. Baturin's study of the "Productive Formation" of Baku is worth while. Although his paper is titled "Paleogeography on the Basis of Terrigenous Components" and is concerned to some extent with methods of study, theories of sedimentation, and quantitative investigations of sediments, he contributes considerable knowledge about the oil sand, 5,000 feet thick, which produces most of Russia's oil at the present time. According to Baturin's view of the matter, the "Productive Formation" of Pliocene age, has a kyanite-ilmenite mineral assemblage or facies, whereas the local rocks of the Caucasus are of volcanic derivation and possess pyrox-

[1] Barnsdall Oil Company. Manuscript received, December, 1939.

ene-hornblende facies. He therefore concludes that the material came from the north by way of the Paleo-Volga in Pliocene time, was eroded from the crystalline rocks of the Russian platform and not the Caucasus, and dropped in the vicinity of Baku as a delta deposit of the old Volga.

To those having a regional interest in the Permian, L. V. Pustovalov's paper titled "Conditions of Sediment Formation during the Upper Permian" is informative. While discarding the idea that the Russian Upper Permian Redbeds are desert deposits, Pustovalov substitutes a new concept, with accompanying proof, that they are delta accumulations synchronous with the Zechstein of western Europe. Besides a detailed description of the stratigraphy and lithology of the redbeds, he emphasizes the importance of strata thickness measurements in deltas. Previous measurements indicated the beds as exposed along a large monocline were 30,000 feet thick. However, within a few kilometers excessive thinning of the beds occurs, making it appear that foreset dip and not regional formation dip had been used in older calculations. By detailed geophysical work the thickness of the delta blanket was thoroughly restudied and the true thickness of some 4,000 feet obtained.

"A New Method for the Determination of the Conditions of Deposition of Ancient Sands" by L. B. Rukhin will be tempting to those mathematically minded gentlemen who may tend to believe that the ancestry, transporting medium, time and place of deposition and true inwardness of every little sand grain or group of grains can be expressed by a formula, be it ever so long. Equally impressive in another phase of technique is S. S. Stanov's article, "Application of the Method of Centrifuging in Weakly Diffusing Media to the Mineralogical Study of Sedimentary Rocks." According to the annotation, "a method of separation is proposed which it is claimed can separate monomineral fractions within a 0.001 change of specific gravity and works even in particles not larger than 1 micron."

The other progress report dealing with foreign items exclusively contains 302 titles in German and is compiled by Carl W. Correns of the Sediment-petrographisches Institute at Göttingen. Besides general references he classifies the papers as to their particular subject matter: weathering, clastic sediments, clays, chemical and biogenic sediments, organic sediments and diagenesis.

Particular fields of sedimentation are favored with five other reports as follows.

Transportation and deposition: "Annotated Bibliography of Sedimentation Studies by the Soil Conservation Service, 1938–1939," by Carl B. Brown. (24 references given.)

"Selected List of References on the Transport of Detritus," by Lorenz G. Straub. (122 references given.)

Calcareous sediments: "Bibliography of Recent Advances in the Field of Calcareous Sediments," by Robert O. Vernon. (94 references.)

Glacial sediments: "References on Glacial Sediments, 1934–1938," by Richard Foster Flint. (91 references.)

Technique: "The Pipette Method Modified for Mass Production," by Gordon Rittenhouse.

With the successful completion of the book *Recent Marine Sediments*, it is probable that the future will find the Committee diverting its attention a little from the study of recent sediments, which they have so capably handled, and concentrating perhaps more on ancient sedimentary deposits. As planned at present, considerable time will be devoted to studies of dia-

genesis and of weathering. Both are intensely interesting but of the two, most petroleum geologists will probably welcome information on diagenesis with the greater enthusiasm.

OIL SHALE AND CANNEL COAL, BY THE INSTITUTE OF PETROLEUM

REVIEW BY HUGH D. MISER[1]
Washington, D. C.

Oil Shale and Cannel Coal, Proceedings of a Conference held in Scotland, June, 1938. xix plus 473 pp., 74 figs., 5 pls. Cloth, 6.5 by 9.25 inches. Published by the Institute of Petroleum, University of Birmingham, Edgbaston, Birmingham, 15, England. Price, 30 s.

A conference on oil shale and cannel coal, organized by the Institute of Petroleum, with the coöperation of numerous scientific and technical societies in Great Britain and other countries, was held in Scotland on June 6–10, 1938. The objects of the conference were twofold: to provide the opportunity for a review of the present state of knowledge regarding the geology, mining, treatment, and utilization of oil shale and cannel coal in all countries where these materials occur; and to consider the problems of increasing oil supplies from indigenous sources of such materials.

The holding of the conference in Scotland—the first conference of an international character devoted solely to oil shale and cannel coal—was especially fitting, for it was there that James Young, who was born in Glasgow, obtained patents in 1850 from which the world's oil-refining industry may be said to have originated. A picture of James Young appears as a frontispiece for the volume, and a brief biography of him written by H. R. J. Conacher follows the foreword and the introduction. In the biography is a description of James Young's development in 1848 of mineral naphtha that was flowing from the roof of a coal seam at the Riddings Colliery in Derbyshire and of his subsequent development of a process patented by him in 1850 for the extraction of oil products from cannel, after the flow of naphtha had dwindled and thus provided an inadequate supply for his operations.

The papers that follow in the volume describe not only the character of the oil shales and cannel coals but also the mining, processing, and other technical features of such shales and cannels in Scotland and in many other parts of the world. All the papers are published in English. They and their authors are listed here; and they are followed by brief comments on the nature and development of the deposits, but relatively little space in the present review is devoted to the technical features of mining and treatment which are fully described in many of the papers.

"Conditions of Deposition of the Oil Shales and Cannel Coals of Scotland," by M. Macgregor.
"D'Arcy Exploration Company's Search for Petroleum in Scotland," by B. K. N. Wyllie.
"Geological Notes on the Borings for Oil now in Progress at Cousland and D'Arcy, Midlothian," by F. W. Anderson and J. B. Simpson.
"The Nature of Scottish Cannels," by W. J. Skilling.
"Coorongite and Its Occurrence," by H. R. J. Conacher.
"Further Discoveries of Sapropelic Deposits in the Coorong Region of South Australia," by Prof. Sir Douglas Mawson.

[1] U. S. Geological Survey. Manuscript received, December, 1939.

"Seventy-Five Years of Oil-Shale Mining," by J. B. Sneddon, W. Caldwell and J. Stein.
"Safety in Scottish Oil-Shale Mines," by A. Winstanley.
"The Former Cannel Oil Industry in North Wales and Staffordshire," by H. P. W. Giffard.
"The Retorting of Oil Shales in Scotland," by D. Stewart and C. E. Forbes.
"Hundred Years of the Chemical Investigation of an Oil Shale: The Chemical Constitution of the Estonian Oil Shale 'Kukersite'," by Paul N. Kogerman.
"The Occurrence and Application of Kukersite in Estonia, with Particular Reference to the Plant of the A/G 'Esimene Eesti Polevkivitoostus' (First Estonian Oil Shale Industry)," by K. Luts.
"The Eesti Kiviöli Tunnel-Oven Process of Low-Temperature Carbonization," by K. Keltser.
"The Davidson Rotary Retort," by T. M. Davidson.
"The Distillation of Pulverized Bituminous Shales," by Ch. Ab-der-Halden.
"Use of Recycled Distillation Gases in Retorting Oil Shale," by J. Teillard d'Eyry.
"The Oil Shales of Australia," by E. E. Kurth and L. J. Rogers.
"Oil Shales of Canada," by A. A. Swinnerton.
"Oil Shale and Shale Oil: A Brief Review of Work by the United States Bureau of Mines," by A. J. Kraemer.
"The Bituminous-Shale Industry in France," by J. Siegler.
"Shale-Oil Production in Sweden," by Sven V. Bergh.
"The Development of the Shale Oil Industry in Manchuria," by T. O'Hashi and T. Kukuzawa.
"Shale-Oil Industry in Brazil," by C. E. Nabuco de Araujo, Jnr., and Luiz Mariti.
"Shale and Cannel Deposits in Czechoslovakia," by Ferdinand Schulz.
"The Laboratory Testing of Oil Shale," by W. Robert Guy.
"The Mineral-Oil Industry in Scotland, Its Raw Materials and Methods," by H. R. J. Conacher.
"Refining of Shale Oil in Scotland," by G. H. Smith and W. B. Peutherer.
"Motor Fuels from Cracking Shale Oils," by Gustav Egloff, J. C. Morrell and G. B. Zimmerman.
"Treatment of Shale Oil by Hydrogenation," by M. Pier.
"Refining and Resistance to Gum Formation of Motor Spirit from the Bituminous Shales of Autun," by J. Friess.
"The Recent Survey of Scottish Cannel," by W. M. Cumming and H. B. Nisbet.
"Assessing the Value of Oil Shales and Cannels," by R. A. Mott and C. E. Spooner.
"Production of Oils from Cannel," by J. Jamieson and J. G. King.
"The Utilization of Oil Shales and Cannel Coals in Connection with the Production of Synthetic Oils," A. J. V. Underwood.

The valuable oil shales of Scotland occur in the Oil-Shale group of the Calciferous sandstone series which is equivalent to a portion of the Mississippian of the United States. This group, which attains a thickness of 4,800 feet, was laid down in an irregular inland depression in which alternating lagoonal and estuarian conditions of sedimentation prevailed. The occurrence of marine beds at certain horizons shows, however, that at times the sea gained access to the lagoons. Although detailed correlation of the sediments is made difficult by the frequent variations in their thickness and character, some horizons and groups of strata may be followed over wide areas and the following generalized succession appears to recur again and again.

(a) Oil shale.
(g) Dark bituminous mudstones containing thin ribs of limestone with entomostraca (minute crustaceans).
(f) Entomostracan limestone.
(e) Dark bituminous mudstones with thin, limy, and often oölitic cement stones.
(d) Mudstones with sandy ribs or plies.
(c) Sandstone.
(b) Bituminous mudstones with entomostraca and cement-stone ribs.
(a) Oil shale.

The typical Scottish oil shale is a fine-grained, tough and often flexible material, black or brownish in color, and minutely laminated; it consists essentially of an argillaceous or clayey base containing varying quantities of organic matter of various kinds, to the oil-yielding portions of which the names "kerogen" and "pyrobitumen" have been provisionally given. Most of the shale is composed of finely divided, apparently structureless material which even microscopic examination can not always resolve into its components. The recognizable constituents include (a) minute carbonized fragments of plants, (b) occasional microspores, (c) shells of minute crustaceans (entomostraca) and fish remains, (d) mineral matter, such as sand grains, crystals of pyrites, etc., and (e) "yellow bodies" which recent work appears to have demonstrated to be the remains of fossil algal colonies.

There is no evidence that animal matter has played any appreciable part in giving oil shales their valuable properties. These properties are associated with the content of vegetable matter and this has been derived in part from the finely divided drifted debris of land plants, and in part from plants (algae) that grew in the lagoons themselves.

The first oil-shale mine in Scotland was opened in 1859 in response to the search for new materials to supplement the approaching exhaustion of the supply of cannel coal, as a source of oil. This opening was the forerunner of a rapidly expanding industry and by 1865 about 120 oil works were in operation. No definite figures are available as to the output of oil shale in that year, but in 1875 the total output was 423,422 tons. The subsequent production of oil shale in steps of ten years is here given.

1885	1,741,750	tons
1895	2,236,224	"
1905	2,491,885	"
1915	2,992,676	"
1925	2,458,052	"
1935	1,408,371	"

In 1919 all the oil companies then operating in Scotland were brought under one management and controlled by Scottish Oils, Ltd., a subsidiary of the present Anglo-Iranian Oil Co., Ltd. The output of shale from the mines (twelve in number) is conveyed to five crude-oil works where crude oil, scrubber naphtha, and ammonia liquor are obtained from the shale by retorting. The crude oil and naphtha are then dealt with in the Pumpherston refinery, where various grades of oil, motor spirit, and wax are made ready for the market. The workable seams vary from 4 to 12 feet in thickness and the yield of crude oil varies from 16 to 40 imperial gallons per ton. It is interesting to note that, as a general rule, the lower the oil shale in the geological sequence, the poorer the yield of oil per ton.

The cannel coals in Scotland are found in the Lower Limestone group, in the Limestone Coal group, in the Upper Limestone group, and in the Productive Coal Measures—a sequence of rocks equivalent to a portion of the Mississippian and Pennsylvanian of the United States. In most cases they are closely associated with ordinary bituminous coals. The term cannel, which has been somewhat loosely used, was originally applied to a coal (candle coal), that gave a high yield of illuminating gas, and certain types that cracked freely on ignition were referred to as parrots. These cannels and parrots were formerly exploited both for the manufacture of crude oil for distilla-

tion and for the enrichment of coal gas. At present, however, there is little demand for them.

The generally lenticular mode of occurrence of cannels in Scotland, their association with ordinary coals, their content of fossil colonial algae ("yellow bodies") and the presence in them of scales, teeth, and spines of fresh-water fish, indicate formation in lakes or pools among the swamp-forests of Carboniferous times. The oil yield appears to have a definite relation to algal content. In the cannels of relatively lower oil yield the proportion of "yellow bodies" to groundmass is much smaller. By far the richest oil yield was that of the Boghead cannel, a seam found near the base of the Productive Coal Measures in the Bathgate-Armadale district. This seam, which yielded as much as 120 or even 130 imperial gallons of oil per ton, has long been exhausted, and no other deposit of comparable richness is known. However, there do exist important reserves of cannel at certain horizons.

The "yellow bodies" of the rich cannels or bogheads of Scotland represent colonies of a fossil alga that does not differ in any material respect from the living alga *Botryococcus braunii*. This alga occurs in vast numbers in certain lakes among which are the Coorong lagoons on the shore of South Australia where a substance known as coorongite is derived from the alga. Coorongite, which is described in the volume here reviewed, resembles asphalt or crude india rubber, and associated with it in the same region are two other forms of algal sapropelic deposits. One of these is a thick deposit of gelatinous slime, now accumulating, which is rich in diatoms and contains the gelatinous remains of filamentous and other algae. The other is a gelatinous rubber-like material met with over a wide area at a depth of a few feet beneath the surface soil and clay, apparently on the floor of a former large lake basin.

Some crude petroleum is encountered in the shale pits and coal mines of Scotland and much or possibly all of it appears to be a product of distillation of shale bands and coal seams by igneous intrusions. Intrusive sheets and dikes are widespread in the Scottish Carboniferous and the amount of oil shale, which has been devolatilized by this agency, is enormous. The crude petroleum so liberated would behave more or less like petroleum generated by bacterial or chemical decomposition of organic materials and would tend to be preserved in the sandstone members of the Oil-Shale series, should these contain well sealed traps. The D'Arcy Exploration Company selected the D'Arcy-Cousland anticline as the most promising structure in the shale-field area and started drilling in September, 1937. Acceptance of the igneous distillation of much of the free oil and gas in the shale mines and in the D'Arcy well was not believed, however, to exclude the possibility that, locally, the transformation of the oil-forming materials might have resulted in a free petroleum without the intervention of heat. Geologic notes on the well of the D'Arcy Exploration Co. (Anglo-Iranian Oil Co.) at Cousland and the D'Arcy well drilled by the Anglo-American Oil Co. are given in the volume.

An account of the former cannel-oil industry in North Wales and Staffordshire, where the cannels are found in the Coal Measures, is given. The two principal reasons for the decline of the cannel-oil industry here, as in Scotland, were the discovery of petroleum in America, which led to the importation of illuminating oil from the United States, and the introduction of incandescent-gas mantles which no longer necessitated the manufacture of gas of such a high degree of luminosity.

The oil shales of Australia occur in the Coal Measures. They include the so-called kerosene shale of New South Wales which is a rich torbanite (boghead cannel) and also include oil shale in Tasmania which is poor in quality, yielding an asphaltic and highly sulphurous oil on distillation. These deposits and their development are described in the volume here reviewed.

In Estonia the production of illuminating gas from oil shale known as "kukersite" occurring in Middle Ordovician strata was begun during the World War and was followed later by the production of shale oil which reached 109,358 tons in 1937. The character and utilization of the oil shale are described in several papers.

The two best-known deposits of bituminous shale in France are: one at Autun (Saône-et-Loire), and the other in the basin of Aumance (Allier). Both are of Permian age and the shale in them is very much like Scottish shale, although not so rich. The French bituminous shale industry dates back a hundred years (since about 1838). The deposit at Saône-et-Loire has been constantly developed since it was opened; that in Allier ceased working in 1914, at the outbreak of the war, but started again in recent years on a smaller scale.

Sweden possesses large deposits of oil shales belonging to the Cambrian-Silurian period. The deposits were investigated as long ago as the seventh decade of the nineteenth century and attempts to develop them on a commercial scale have been made at different times. In 1925 a plant was erected at Kinne-Kleva. It is owned by the Swedish State under the administration of the Naval Board and is the only plant running at present.

The oil-shale industry in Fushun (Manchukuo) dates from 1909, and at the present time is producing about 150,000 tons of oil per annum. The shale deposit covers an area of about 11 square miles; the thickness is about 450 feet; and the estimated quantity of shale available is about 540 million tons. The shale lies above a coal bed, and the average oil content is about 5 to 6 per cent. The coal is worked by the open-pit method and the shale is thus removed incidental to the mining of the coal. From the point of view of the quantity of shale treated, this is one of the largest enterprises in this particular industry in the world. Furthermore, it is responsible for a good share of the total home production of crude oil in the Japanese Empire.

In former Czechoslovakia the only bituminous shale suitable for commercial development is found in the Permian seam of the Kladno coal basin. This shale is used for gas making and for general fuel purposes. High-grade cannel coal has been mined for a long time in the coal basin near Plzen (Western Bohemia). This seam is now almost exhausted. A Tertiary coal, known as "Boghead," is being mined in Western Bohemia. It seems to be a "waxy" coal which has been modified by physico-chemical action.

In addition there are chapters devoted to the oil shales of Canada, the United States, and Brazil.

In one of the papers (J. Jamieson and J. G. King, pp. 452–467) near the end of the volume is found the following significant statement: "Continued search still fails to discover in Great Britain sources of natural oil which are other than slight. If, therefore, the country must have indigenous oil fuels, these must be produced in some manner from coal or allied materials." As stated at the outset (page xi) one of the objects of the conference on oil shale and cannel coal was "to consider the problems of increasing oil supplies from indigenous sources of such materials."

The Institute of Petroleum is to be congratulated for its successful organization and management of the conference on oil shale and cannel coal and for the publication of the many authoritive papers on all phases of these materials in all the countries where they are found.

RECENT PUBLICATIONS

BOLIVIA

De Bodenschätze Bolviens (The Mineral Resources of Bolivia), by Fr. Ahlfeld and J. Muñoz Reyes. 199 pp., 65 figs., map of mineral deposits. Gebrüder Borntraeger, Berlin (1939). Price, RM 28. On orders outside Germany, 25 per cent discount.

BRAZIL

* "Contribution to the Geology of Petroleum in Southwest Mato Grosso," by Glycon de Paiva and Viktor Leinz. *Brasil Dept. Nac. Prod. Min., Div. Fomento da Produção Mineral Bol. 37* (Rio de Janeiro, 1939). 98 pp., 8 maps and sections, 12 photographs. In Portuguese. English summary. pp. 9–14.

CENTRAL AMERICA

* "Geographical-Geological Investigations and Explorations in the Northwestern Part of Central America," by F. K. G. Müllerried. *Inst. Panamer. Geogr. Hist. Pub. 38* (Mexico, D. F., 1939), 52 pp., 30 illus. In Spanish.

COLORADO

* "Paleozoic Section in the Vicinity of Dotsero, Colorado," by Charles Fernando Bassett. *Bull. Geol. Soc. America*, Vol. 50, No. 12, Pt. 1 (New York, December 1, 1939), pp. 1851–66; 2 pls. 1 fig.

ENGLAND

* "Results of Drilling for Oil in Southern England," by L. Happel. *Geologie en Mijnbouw*, Vol. 1, N.S., No. 8 (August, 1939), pp. 185–93; 3 figs. In German. Geologisch Mijnbouwkundig Genootschap voor Nederland en Koloniën, Carel van Bylandtlaan 30, Den Haag, Nederland.

EUROPE

Der Bau der Alpen (The Structure of the Alps), by Leo M. Krasser. 40 pp., 1 map, 1 table, and 14 photographs in appendix. Gebrüder Borntraeger, Berlin (1939). Price, RM 3.75. On orders outside Germany, 25 per cent discount.

FRANCE

* "Origin of Oil in the Lower Oligocene of the Upper Rhine Valley, Pechelbronn Field," by L. U. de Sitter. *Geologie en Mijnbouw*, Vol. 1, N.S., No. 9 (September, 1939), pp. 221–30; 3 figs. In English.

GENERAL

* "Bibliographic Index of North American Devonian Cephalopoda," by E. M. Kindle and A. K. Miller. *Geol. Soc. America Spec. Paper 23* (December 28, 1939). 179 pp.

* "Abstracts of The Geological Society of America, December Meeting at Minneapolis." *Bull. Geol. Soc. America*, Vol. 50, No. 12, Pt. 2 (New York, December 1, 1939), pp. 1899–1944.

* "Abstracts of The Geological Society of America, August Meeting at Berkeley." *Ibid.*, pp. 1945–62.

* "Abstracts of the Paleontological Society, December Meeting at Minneapolis." *Ibid.*, pp. 1963–70.

* "Abstracts of the Paleontological Society, August Meeting at Berkeley." *Ibid.*, pp. 1971–74.

* "Abstracts of Section E, American Association for the Advancement of Science, December Meeting at Columbus." *Ibid.*, pp. 1975–94.

* "Abstracts of Section E, American Association for the Advancement of Science, June Meeting at Milwaukee." *Ibid.*, pp. 1995–2016.

* "Lower Mississippian Rocks of the East-Central Interior," by Paris B. Stockdale. *Geol. Soc. America Spec. Paper 22* (December 20, 1939). 248 pp., 26 pls. 2 figs.

* "Bibliography of Seismology, No. 2, Items 4379–4503, April, May, June, 1939," by Ernest A. Hodgson. Publications of the Dominion Observatory, Vol. 13, Ottawa, Canada (1939). 19 pp. Price, $0.25.

ILLINOIS

"Preliminary Geologic Maps of the Pre-Pennsylvanian Formations in Part of Southwestern Illinois," by Stuart Weller and J. Marvin Weller. *Illinois State Geol. Survey Div. Dept. Investig. 59* (Urbana, 1939). 15 pp., 3 pls., 2 figs. Price, $0.25.

"Preliminary Geologic Maps of the Mississippian Formations in the Dongola, Vienna, and Brownfield Quadrangles," by Stuart Weller and Frank F. Krey. "Explanation and Stratigraphic Summary," by J. Marvin Weller. *Ibid., R. I. 60.* 12 pp., 1 pl., 1 fig. Price, $0.25.

MEXICO

* "Paleontological and Stratigraphical Notes on the Mezquital Valley, State of Hidalgo," by F. K. G. Müllerried. *Sobretiro Anales Escuela Nac. Ciencias Biologicas*, Vol. 1, No. 2 (Mexico, D. F., 1939), pp. 225–56, Pls. 40–43. In Spanish. English and German résumé, pp. 245–46.

TEXAS

* "Marine Pleistocene of Texas," by Horace G. Richards. *Bull. Geol. Soc. America*, Vol. 50, No. 12, Pt. 1 (New York, December 1, 1939), pp. 1885–98; 3 pls.

TURKEY

* Maden Tetkik ve Arama, Evstitüsü Mecmuase, No. 4 (Ankara, 1939), contains, among others, the following articles in its special number for the 16th anniversary of the Republic. "Research and Possibilities of Petroleum Discoveries," by Cevat E. Taşman, pp. 42–46. In Turkish. "New Geological Viewpoint for the Mining Industry in the Western Coal Basin of Northern Anatolie," by P. Arni, pp. 46–55, in Turkish; pp. 55–63, in German; 1 sketch map, 2 geological sections. "Review of Reconnaissance in the Eastern Coal Basin of Anatolie," by W. S. Graney, pp. 64–75, in Turkish; pp. 75–88, in German; 2 maps, plate of geologic sections, stratigraphic column, 8 photographs.

UTAH

* "Geographic and Geologic Sketch of the Capitol Reef Region, Utah," by Herbert E. Gregory and J. C. Anderson. *Bull. Geol. Soc. America*, Vol. 50, No. 12, Pt. 1 (New York, December 1, 1939), pp. 1827–50, 9 pls., 2 figs.

WEST VIRGINIA

* *Greenbrier County*, by Paul H. Price and E. T. Heck. *West Virginia Geol. Survey* (Morgantown, 1939), 846 pp., 53 pls., 23 figs., 2 maps in separate box.

* "Limestones of West Virginia," by John B. McCue, John B. Lucke, and Herbert P. Woodward. *West Virginia Geol. Survey*, Vol. 12 (1939). 560 pp., 38 pls., 15 figs., folded map.

ASSOCIATION DIVISION OF PALEONTOLOGY AND MINERALOGY

* *Journal of Paleontology* (Tulsa, Okla.), Vol. 14, No. 1 (Jan., 1940).

"Fauna of the Basal Bonneterre Dolomite (Upper Cambrian) of Southeastern Missouri," by Christina Lochman

"Fauna of the Van Oser Beds," by Clinton R. Stauffer

"Upper Devonian Rugose Corals of the Nevada Limestone," by Erwin C. Stumm

"Upper Paleozoic Cephalopods from Central Hunan, China," by King Koo Chao

"*Lebetocrinus*, a New Crinoid Genus from the Upper Border of Indiana," by Edwin Kirk

"*Aparchites canadensis*, a New Devonian Ostracode from the Onondaga of Ontario," by Madelein A. Fritz

"Fossil Lygaeidae (Hemiptera) from Florissant," by Robert L. Usinger

"A Toothless Bird from the Cretaceous of Alberta," by R. M. Sternberg

"Lucite as an Aid in Studying Hard Parts of Living and Fossil Animals," by Robert R. Shrock

* *Journal of Sedimentary Petrology* (Tulsa, Okla.), Vol. 9, No. 3 (Dec., 1939).

"Beach Sands from Bunbury, Western Australia," by Dorothy Carroll

"The Sediments of Devils Lake, a Eutrophic-Oligotrophic Lake of Southern Wisconsin," by W. H. Twenhofel and V. E. McKelvey

"Application of Photo-Electric Cell to the Measurement of Pebble Axes for Orientation Analysis," by W. C. Krumbein

"Differential Packing as a Possible Display of Bedding," by W. D. Keller

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
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THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ASSOCIATE MEMBERSHIP

John Schlagle Kelly, Houston, Tex.
Fred E. Smith, M. T. Halbouty, J. Brian Eby

FOR TRANSFER TO ACTIVE MEMBERSHIP

John L. Abbott, Fort Worth, Tex.
David Donoghue, O. F. Hedrick, C. E. Yager

Harry Wendell McCobb, Palembang, Sumatra, N. E. I.
Raymond Leibensperger, R. E. Somers, R. E. Sherrill

Charles Hurst Sample, Houston, Tex.
Phil F. Martyn, C. A. Warner, Don E. Mathes

Homer M. Wilson, Marathon, Tex.
H. Smith Clark, Alfred Cumming, Wesley G. Gish

(Continued on page 406)

THE BOULEVARD ROOM, STEVENS HOTEL, CHICAGO

The twenty-fifth annual meeting of the Association will be held at the Stevens Hotel, April 10–12, 1940

TWENTY-FIFTH ANNUAL MEETING, CHICAGO, APRIL 10–12, 1940

The twenty-fifth annual meeting of The American Association of Petroleum Geologists at Chicago, April 10–12, may break records in several ways. First of all, it marks a quarter century of organized coöperation among geologists in the application of their science to the business of exploring for oil and gas. In 25 years the technique of oil finding has changed amazingly and the 1940 "Symposium on New Ideas in Petroleum Exploration," sponsored by the Association research committee, will outline the latest methods and equipment.

This convention will be made up of concurrent and consecutive sessions of The American Association of Petroleum Geologists, the Society of Economic Paleontologists and Mineralogists, and the Society of Exploration Geophysicists. Joint sessions are being arranged for the first day, April 10.

The research committee, A. I. Levorsen, chairman, is sponsoring a full afternoon session on April 10 which will be of general interest to all groups. It is entitled "A Symposium on New Ideas in Petroleum Exploration." Each speaker is to present some of the new ideas in his field and point out their significance. The speakers are to key their remarks to the present and future. The tentative half-day program follows.

1. A. I. Levorsen, chairman: Introduction
2. Paul E. Fitzgerald, Dowell, Inc., Tulsa: Chemical Engineering
3. C. V. Millikan, Amerada Petroleum Corporation, Tulsa: Petroleum Engineering
4. E. A. Eckhardt, Gulf Research and Development Company, Pittsburgh: Geophysics
5. E. E. Rosaire, Subterrex, Houston: Geochemical Exploration
6. F. H. Lahee, Sun Oil Company, Dallas: Where Will Our Young Graduates in Petroleum Geology Acquire Field Experience?
7. E. DeGolyer, of DeGolyer, MacNaughton, and McGhee, Dallas: Future Position of Petroleum Geology in the Oil Industry

This symposium will be followed by an hour of open discussion.

This will be the first annual meeting of the A.A.P.G. to be held so far north. Discoveries of the past few years in the northern Mid-Continent have moved centers of field activity. Chicago is an educational center of a large region whose schools of science have contributed to the membership growth of the Association and to the scientific prestige of Association publications.

Special transportation arrangements are being made by local groups. The Houston Geological Society is sponsoring a special train starting from Houston probably on April 8, and arriving in Chicago early on April 10. Special cars or groups will be added en route, as at Fort Worth, Oklahoma City, Wichita, and other points.

There will not be special convention railroad rates for this meeting (railroads are no longer in a position to grant convention rates), but those planning to attend will find upon early inquiry at their local ticket office that favorably low round-trip excursion rates with stop-over privileges are generally available.

Headquarters: Stevens Hotel, Chicago
General chairman: Verner Jones, Magnolia Petroleum Co., Mattoon
Technical program: A. H. Bell, Illinois Geological Survey, Urbana
Arrangements: J. V. Howell, Mt. Vernon
Trips: M. M. Leighton, Illinois Geological Survey, Urbana

ASSOCIATION COMMITTEES

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ED. W. OWEN, *secretary*, L. H. Wentz (Oil Division), San Antonio, Texas
DONALD C. BARTON (deceased, July 8, 1939)
L. MURRAY NEUMANN, Carter Oil Company, Tulsa, Oklahoma
W. A. VER WIEBE, University of Wichita, Wichita, Kansas

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R. K. DEFORD (1941)	VIRGIL PETTIGREW (1940)	ROBERT H. WOOD (1941)
C. E. DOBBIN (1941)	PAUL H. PRICE (1941)	C. E. YAGER (1941)

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PAUL L. APPLIN (1940)	J. V. HOWELL (1940)	JOHN N. TROXELL (1940)
A. R. DENISON (1940)	MAX L. KRUEGER (1940)	

ASSOCIATION COMMITTEES

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RESEARCH COMMITTEE

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M. G. CHENEY (1942), *vice-chairman*, Coleman, Texas

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C. W. TOMLINSON (1940), *chairman*, 509 Simpson Building, Ardmore, Oklahoma

1941	1942
MONROE G. CHENEY	JOHN E. ADAMS
ROBERT H. DOTT	RAYMOND C. MOORE

COMMITTEE ON APPLICATIONS OF GEOLOGY

CARROLL E. DOBBIN (1942), *chairman*, U. S. Geological Survey, 224 Custom House, Denver, Colorado

J. CLARENCE KARCHER (1942), *vice-chairman representing geophysics*, 406 Continental Building, Dallas, Texas

CAREY CRONEIS (1942), *vice-chairman representing paleontology*, Walker Museum, University of Chicago, Chicago, Illinois

1940	1941	1942
H. S. MCQUEEN	HAL P. BYBEE	LUTHER E. KENNEDY
B. B. WEATHERBY	HENRY C. CORTES	CHALMER J. ROY
	HAROLD W. HOOTS	EARL A. TRAGER
	E. E. ROSAIRE	

COMMITTEE STUDYING METHODS OF ELECTING OFFICERS

WALTER R. BERGER, *chairman*, Trinity Building, Fort Worth, Texas

R. M. BARNES	A. R. DENISON	C. E. DOBBIN

FOURTEENTH ANNUAL MEETING, SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS, CHICAGO, APRIL 11, 1940

The fourteenth annual meeting of the Society of Economic Paleontologists and Mineralogists will be held in connection with the Association meeting at the Stevens Hotel, Chicago, April 11. The program committee is composed of the following.

W. C. Krumbein, chairman, University of Chicago
James B. Dorr, Shell Oil Company, Inc., Houston, Texas
C. G. Lalicker, University of Oklahoma, Norman, Oklahoma
H. G. Schenck, Stanford University, Palo Alto, California

Chairman Krumbein announces that the following authors and papers have been placed on the program in the preliminary plans.

Gayle Scott, president of the Society, Texas Christian University, Fort Worth, Texas: Ecological Factors Controlling the Distribution of Cretaceous Ammonoids in the Texas Area

J. R. Ball, Northwestern University, Evanston, Illinois: Some Silurian Correlations in the Lower Mississippi Valley

M. B. Payne, Richfield Oil Corporation, Bakersfield, California: Type Moreno Cretaceous and Superjacent Eocene, Panoche Hills, California

H. G. Schenck, Stanford University, California: Economically Important Micro-Fossils

M. L. Thompson, Phillips Petroleum Company, Lafayette, Louisiana, and H. J. Bissell, Brigham Young University, Provo, Utah: Pennsylvanian and Permian Fusulinids of the Wasatch Mountains, Utah

M. L. Thompson, Phillips Petroleum Company, Lafayette, Louisiana, and J. C. Hazzard, Los Angeles, California: Permian Fusulinids from the Providence Mountains, California

All titles and abstracts should be in chairman Krumbein's hands now (mid-February) in order to be included in the printed program.

ELEVENTH ANNUAL MEETING, SOCIETY OF EXPLORATION GEOPHYSICISTS, CHICAGO, APRIL 9, 10, AND 11, 1940

The eleventh annual meeting of the Society of Exploration Geophysicists will be held at the Stevens Hotel, Chicago, April 9, 10, 11. This important change of the previous plans of the geophysicists should be given wide publicity as many members will not want to miss the opportunity of attending these concurrent conventions of paleontologists, mineralogists, geophysicists, and geologists. The first day of this meeting will be the day before the technical program of the A.A.P.G. On the second day, the geophysicists and the geologists will meet in a joint program of general interest to all.

W. T. Born is chairman of the arrangements. Titles and abstracts should be sent to him immediately for inclusion in the program. His address is Geophysical Research Corporation, Tulsa, Oklahoma. The following are also serving on the committee, and titles may be sent to them: E. E. Rosaire, Esperson Building, Houston, Texas, and John H. Crowell, Independent Exploration Company, Houston.

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RESEARCH NOTES

RESEARCH COMMITTEE CONFERENCE GROUPS

A. I. LEVORSEN[1]
Tulsa, Oklahoma

The research committee is sponsoring several conference groups in order to study more intensively and collectively some of the fundamental problems of petroleum geology. Each group is to consist of a leader and possibly one or more assistants who are members of the research committee, and as many other members of the Association as show sufficient interest to attend and take part in the discussions. Each conference group will meet at the time of the annual convention and most conferences will be scheduled to convene concurrently the afternoon preceding the annual meeting.

One purpose of these conferences is to furnish an opportunity to those desiring it to meet with others of like interests and to exchange ideas and experiences and otherwise discuss some of the various questions of their common problem. The conferences are scheduled to last for 2 or 3 hours according to the desires of the leader and the conference group. It is hoped that such meetings, in the atmosphere of the conference or round table and composed of relatively small but interested groups, will be worth while, not only to those participating but also to the Association as a whole. We may also expect that over a period of years these conference discussions will result in articles for the *Bulletin;* in the outlining and stimulating of research projects; and in a coördination of the state of our knowledge in various fundamental fields.

The function of the research committee is merely to provide a leader, a time, and a place for these conferences. The results, methods of attack, and scope of the conference are dependent on the leaders and those who participate in the discussions. While the various leaders may continue from year to year to preserve the continuity of the discussions, the personnel will probably change from meeting to meeting, according to those in attendance at the convention and to their changing interest in the problem. Depending on the desires of the members of the Association, there is no reason why an additional number of such conference groups might not be arranged. Following is a preliminary and tentative list of those groups which have already been organized.

Sedimentation and reservoir rocks
Leader: E. Wayne Galliher, Barnsdall Oil Company, Los Angeles, California
Assistants: F. W. Rolshausen, Humble Oil and Refining Company, Houston, Texas
W. C. Krumbein, University of Chicago, Chicago, Illinois
John C. Miller, The Texas Company, Houston, Texas

Oil-field waters
Leader: L. C. Case, Gulf Oil Corporation, Tulsa, Oklahoma
Assistants: Ralph H. Fash, Fort Worth Laboratories, Fort Worth, Texas
Howard S. Bryant, Skelly Oil Company, Tulsa, Oklahoma

Origin and evolution of oil
Leader: Monroe G. Cheney, Anzac Oil Corporation, Coleman, Texas
Assistant: W. P. Rand, Gulf Oil Corporation, Pittsburgh, Pennsylvania

Migration and accumulation of oil
Leader: F. M. Van Tuyl, Colorado School of Mines, Golden, Colorado

[1] Chairman, research committee.

Assistant: Ben H. Parker, Colorado School of Mines, Golden, Colorado
Relation of oil analyses to stratigraphy
Leader: N. W. Bass, U. S. Geological Survey, Tulsa, Oklahoma

In addition to these conference groups which are aimed at the advancement of our knowledge of fundamental problems, another group of conferences or luncheons will be scheduled by the following working units of the research committee, to which anyone interested will also be welcome.

Tectonic map of the United States
Leader: Philip B. King, U. S. Geological Survey, Washington, D. C.
Assistant: T. E. Weirich, Phillips Petroleum Company, Bartlesville, Oklahoma
Foreign geology
Leader: Winthrop P. Haynes, Standard Oil of New Jersey, New York, N. Y.
The Permian system, special volume
Editor: Ronald K. DeFord, Argo Oil Company, Midland, Texas
Stratigraphic oil fields, special volume
Leader: A. I. Levorsen, Tulsa, Oklhoma

Association members interested in any of these conferences or in the formation of additional conference groups are invited to correspond with the research committee members who are active in this phase of our work.

ANNOUNCEMENT

Geochemical Exploration (Soil Analysis) will be the subject of the annual Round Table meeting of the research committee to be held at Chicago on the evening of Tuesday, April 9th at 8:00 P.M. As heretofore it will follow the research dinner which is scheduled for 6:30 P.M. The formal presentation of the topic will be by E. E. Rosaire, Houston, Texas, and Eugene McDermott, Dallas, Texas, after which the meeting will be open to discussion, comment, and question. All who are interested are invited to attend the dinner and the discussion which follows.

A. I. LEVORSEN
Chairman, research committee

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AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

HEWLETT A. RUSSELL, of the Standard Oil Company of Texas, has been transferred from Alabama to Houston, Texas.

WALTER W. SCOTT, chief petroleum engineer for the Humble Oil and Refining Company, died at Houston, Texas, December 7, after a prolonged illness. Scott had been with the company since 1928.

JOSEPH M. DAWSON, of the Gulf Oil Corporation at Houston, Texas, has resigned after 18 years with the organization. He is now special consultant with W. L. Pickens, Lloyd Wheelock, James Collins, and H. J. Porter, independent operators. Dawson was formerly geologist and zone agent in Venezuela, East Texas, and South Texas for the Gulf, with headquarters at San Antonio for 12 years.

The Oklahoma City Geological Society has elected the following officers: president, ALBERT S. CLINKSCALES, Consultant; vice-president, CLYDE H. DORR, of Hall Briscoe, Inc.; secretary-treasurer, F. MABRY HOOVER, Cities Service Oil Company; all of Oklahoma City.

W. A. REITER, chief geologist of the Fohs Oil Company, discussed "Microscopic Fossils in Crude Oil," before the Houston Geological Society, December 7.

F. P. SHEPARD, of the department of geology at the University of Illinois, discussed "Sedimentation Off the California Coast," before the Illinois Geological Society, December 1, at Matoon, Illinois.

The Kansas Geological Society of Wichita has elected the following officers for 1940: president, ANTHONY FOLGER, Gulf Oil Corporation; vice-president, HAROLD O. SMEDLEY, Shell Oil Company; secretary-treasurer, LEE H. CORNELL, Stanolind Oil and Gas Company.

E. A. NEWMAN has resigned as petroleum geologist of the Michigan Geological Survey to become chief geologist of the Smith Petroleum Company, Saginaw.

F. B. PLUMMER, of the petroleum engineering department, University of Texas, talked on the geology of the Dominican Republic before the West Texas Geological Society, at Midland, December 19.

J. F. MAHONEY, chief geologist of the Union Sulphur Company, Sulphur, Louisiana, has resigned to become a consulting geologist.

ELLIOT H. POWERS has succeeded JOHN V. TERRILL as district geologist at Amarillo office of the Gulf Oil Corporation.

JOHN M. CLAYTON, geologist for the Seaboard Oil Company, Dallas, Texas, spoke on "The Producing Formations above the Jackson in Southwest Texas," before the Dallas Petroleum Geologists, December 18.

ALLAN C. TESTER has returned from Colombia, South America, and has resumed active teaching at the State University of Iowa, Iowa City.

M. M. SLOTNICK, of the Humble Oil and Refining Company, addressed the Houston Geological Society, December 14, on the subject, "Gravimetric and Seismic Methods in Exploratory Geophysics."

J. J. RUSSELL, district geologist for the Sinclair Prairie Oil Company, has been transferred from Wichita Falls, Texas, to Columbus, Ohio. L. L. HARDEN, at Eastland, Texas, is now in charge of geological operations for the company in North and West-Central Texas.

The Dallas Petroleum Geologists elected the following officers for the new year: president, W. W. CLAWSON, Magnolia Petroleum Company; vice-president, LEWIS W. MACNAUGHTON, of DeGolyer and MacNaughton; secretary-treasurer, D. M. COLLINGWOOD, Sun Oil Company; PAUL W. MCFARLAND, Sun Oil Company, member of the executive committee.

B. B. WEATHERBY, president of the Geophysical Research Corporation, Tulsa, is chairman of the committee on geology for the International Petroleum Exposition, May 18–25.

DAVID DONOGHUE, consulting petroleum geologist, Fort Worth, Texas, and W. B. DUKE, vice-president of the Fort Worth National Bank, are authors of a printed folder entitled "Loans on Producing Oil Properties."

A conference on the "Early Paleozoic" was held at the University of Oklahoma, Norman, November 4, 1939, sponsored by Sigma Gamma Epsilon. The program was arranged by V. E. MONNETT, head of the geological department, R. H. DOTT, State geologist, and C. E. DECKER, professor of paleontology. IRA H. CRAM, division geologist of the Pure Oil Company, Tulsa, was chairman. These papers were presented: "Outcropping Ordovician and Cambrian Formations of Oklahoma," by C. E. DECKER; "Notes on the Texas Ordovician," by C. L. BAKER, Texas Agricultural and Mechanical College; "Subsurface Cambro-Ordovician of Kansas and Eastern Colorado," by M. S. LITTLEFIELD, Gulf Oil Corporation, Tulsa; "Comparison of Early and Late Paleozoic History of the United States," by T. E. WEIRICH, Phillips Petroleum Company, Bartlesville.

JAMES WILLIS VERNON, associate member-elect of this Association, was found dead on a mountain side near Coalinga, California, December 20, apparently having met with an accident while engaged in geologic field work. He was in the employ of the Union Oil Company of California, Los Angeles. Vernon was born April 7, 1918, at North Platte, Nebraska. He attended the University of Wyoming, Laramie, from 1936 to 1939.

The following officers of the Rocky Mountain Association of Petroleum Geologists were elected, December 18: president, HAROLD N. HICKEY, 810 U. S. National Bank Building, Denver; 1st vice-president, E. H. STEVENS, Colorado School of Mines, Golden; 2nd vice-president, NINETTA DAVIS, 224 Custom House, Denver; secretary-treasurer, DART WANTLAND, 927 Humboldt Street, Denver, Colorado.

The Shawnee Geological Society, Shawnee, Oklahoma, has elected officers for 1940: president, J. LAWRENCE MUIR, Amerada Petroleum Corporation; vice-president, M. C. ROBERTS, The Texas Company; secretary-treasurer, F. SPENCER WITHERS, Atlantic Refining Company.

The officers of the Panhandle Geological Society are: president, E. W. RUMSEY, Shell Oil Company, Inc., Amarillo; vice-president, G. R. CARTER, Gulf Oil Corporation, Amarillo; secretary-treasurer, FRANK N. BLANCHARD, JR., Skelly Oil Company, Pampa, Texas.

Notice of the indefinite postponement of the 18th Session of the International Geological Congress fixed for July 31 to August 8, 1940, in London, has been received for announcement in this country.

ELIOT BLACKWELDER, of Stanford University, was elected president of the Geological Society of America at the Minneapolis meeting last December.

Syracuse University has an opening for an additional instructor in general geology. The work will largely involve laboratory work with elementary students. A doctorate is essential and some measure of commercial experience is very desirable.

CHARLES GILL MORGAN, of the United Geophysical Company, Pasadena, California, returned in January from a 9-month survey of an oil-exploration program in Argentina, Bolivia, and Brazil.

HUGH C. SCHAEFFER, with the United Geophysical Company, has been transferred from Pasadena, California, to the Mid-Continent and Gulf Coast regions. His address is 2416 NW Twentieth, Oklahoma City, Oklahoma.

H. D. PENNEL, geological scout for the Amerada Petroleum Corporation in West Texas has been transferred to Lake Charles, Louisiana.

GEORGE CHARLTON MATSON, fifth president of the Association, died at Tulsa, Oklahoma, January 3, in his 67th year.

RALPH DANIEL REED, twentieth president of the Association, died at Pasadena, California, January 29, in his 51st year.

BURTON E. ASHLEY, of The Texas Company, presented "A Rhodesian Ramble," before the Kansas Geological Society, Wichita, Kansas, January 9.

DARSIE A. GREEN, of The Pure Oil Company, has been transferred from the geological staff at Tulsa, Oklahoma, to the office at Olney, Illinois.

F. W. ROWHER spoke on "Oil Occurrences in Trinidad (B.W.I.), " before the Rocky Mountain Association of Petroleum Geologists at Denver, Colorado, February 5.

New officers of the Michigan Geological Society are: president, W. A. CLARK, Mount Pleasant; secretary-treasurer, C. H. RIGGS, Michigan Geological Survey Division, 21 Sheldon, N.E., Grand Rapids; business manager, S. G. BERGQUIST, Michigan State College, East Lansing.

NORMAN L. THOMAS, Pure Oil Company paleontologist formerly at

Fort Worth, Texas, is division geologist with headquarters at Bakersfield, California.

N. W. BASS, United States Geological Survey geologist of Tulsa, spoke before the Pawhuska, Oklahoma, Kiwanis Club, February 2. His subject was "What Lies beneath the Soil," indicating prolonged oil production from Osage County.

RAYMOND LEIBENSPERGER has been appointed chief geologist of the Standard-Vacuum Oil Company, New York City.

ADDITIONAL MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

(Continued from page 396)

FOR ACTIVE MEMBERSHIP

Walter M. Chappell, Bogota, Colombia, S.A.
T. J. Etherington, Charles E. Weaver, Earl A. Trager

David Arthur Dunn, Lubbock, Tex.
W. I. Robinson, Marion H. Funk, M. A. Stainbrook

Hugh Moore Eley, Dallas, Tex.
Linn M. Farish, John E. Van Dall, Fred Joekel

John Richardson Fanshawe, Westfield, N.Y.
W. T. Thom, Jr., Edward Sampson, John B. Lucke

Edward Harvey Griswold, Midland, Tex.
Edwin A. Wahlstrom, Berte R. Haigh, James FitzGerald, Jr.

David M. Grubbs, Youngstown, Ohio
Linn M. Farish, Cary Croneis, Charles E. Decker

Aden Wayne Hughes, Bakersfield, Calif.
Glenn C. Ferguson, Stanley G. Wissler, Norman L. Thomas

Ross A. Maxwell, Austin, Tex.
Charles E. Decker, Charles N. Gould, Fred M. Bullard

Powell Wesley Miller, Jal, N.Mex.
Delmar R. Guinn, W. I. Robinson, M. A. Stainbrook

Ernest Turnley Nichols, Babo, New Guinea
Harris Cox, W. H. Maddox, George L. Knox

George Bailey Stone, Houston, Tex.
George S. Buchanan, George I. McFerron, J. M. McMillan, Jr.

Richard Ten Eyck, Pomona, Calif.
H. D. Hobson, John B. Sansone, R. M. Barnes

FOR ASSOCIATE MEMBERSHIP

William Hammond Allen, Houston, Tex.
F. W. DeWolf, Harold R. Wanless, Kenneth S. Ferguson

Gene Ballard, Wasco, Calif.
W. D. Cortright, A. W. Vitt, W. D. Kleinpell

Charles Carpenter Bates, Aberdeen, Miss.
Sam Zimerman, E. R. Smith, George E. Wagoner

Albert Breeze Carlisle, Mt. Pleasant, Mich.
George S. Buchanan, William A. Thomas, T. S. Lovering

John Crawford Dunlap, Maracaibo, Venezuela, S.A.
Irion G. Davis, John G. Douglas, G. Edward Manger

Roland W. Garwood, Barranquilla, Colombia, S.A.
Robert S. Breitenstein, James Terry Duce, Fred C. Sealey
Robert D. Hendrickson, Houston, Tex.
Shapleigh G. Gray, Wayne V. Jones, A. P. Allison
John Harris Lupton, III, Beaumont, Tex.
C. B. Claypool, H. W. Rose, Earl T. Apfel
Charles Joseph Monahan, Little Rock, Ark.
J. Harlan Johnson, W. A. Waldschmidt, F. M. Van Tuyl
Walter Neustadt, Jr., New Haven, Conn.
Alan M. Bateman, C. W. Tomlinson, Maynard P. White
Martin Meredith Sheets, Houston, Tex.
Louis C. Roberts, Jr., R. B. Mitchell, Shirley L. Mason
Tomas Suero, Norman, Okla.
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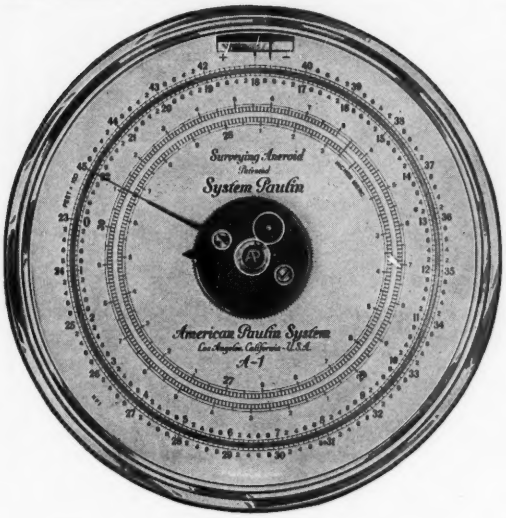

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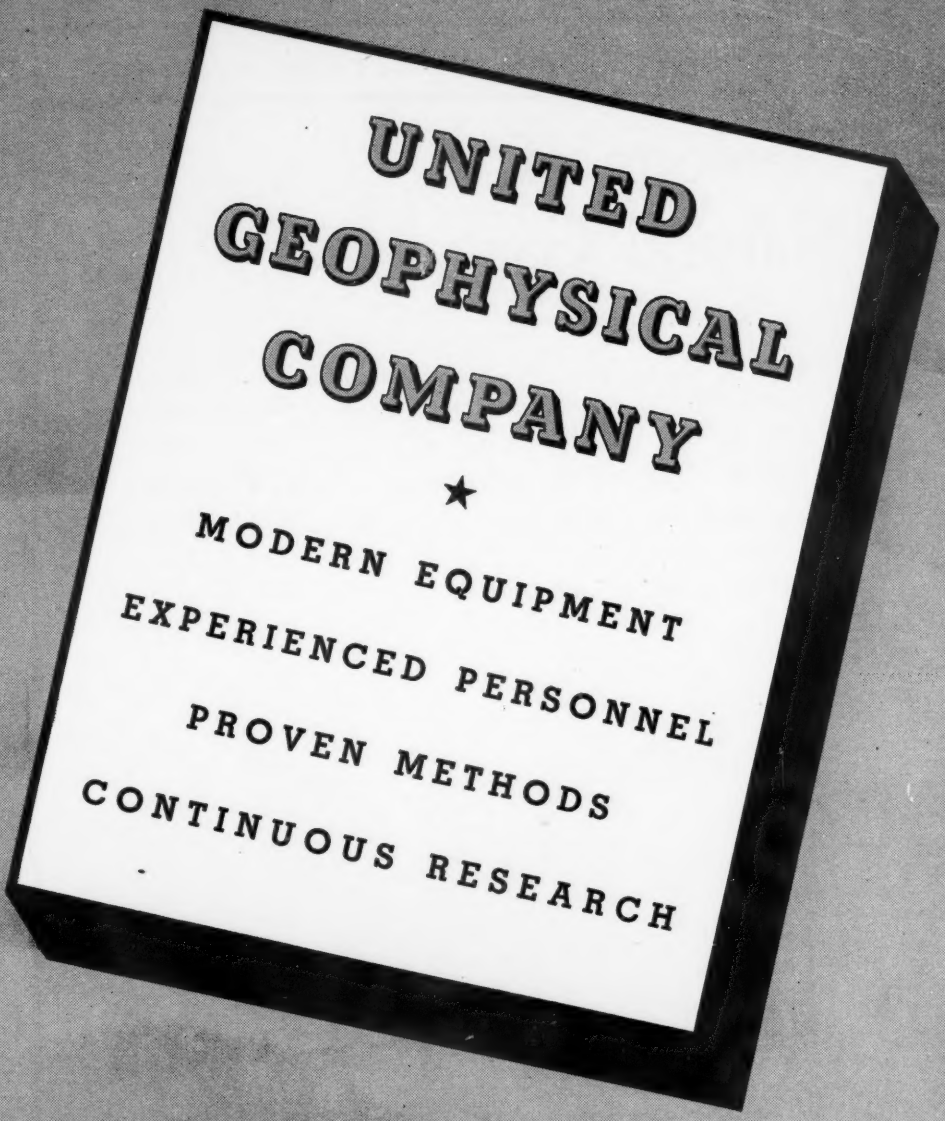

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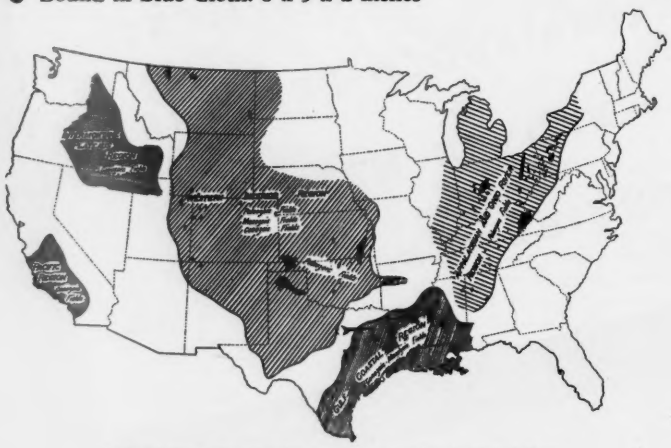

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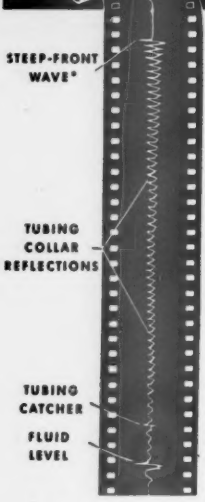

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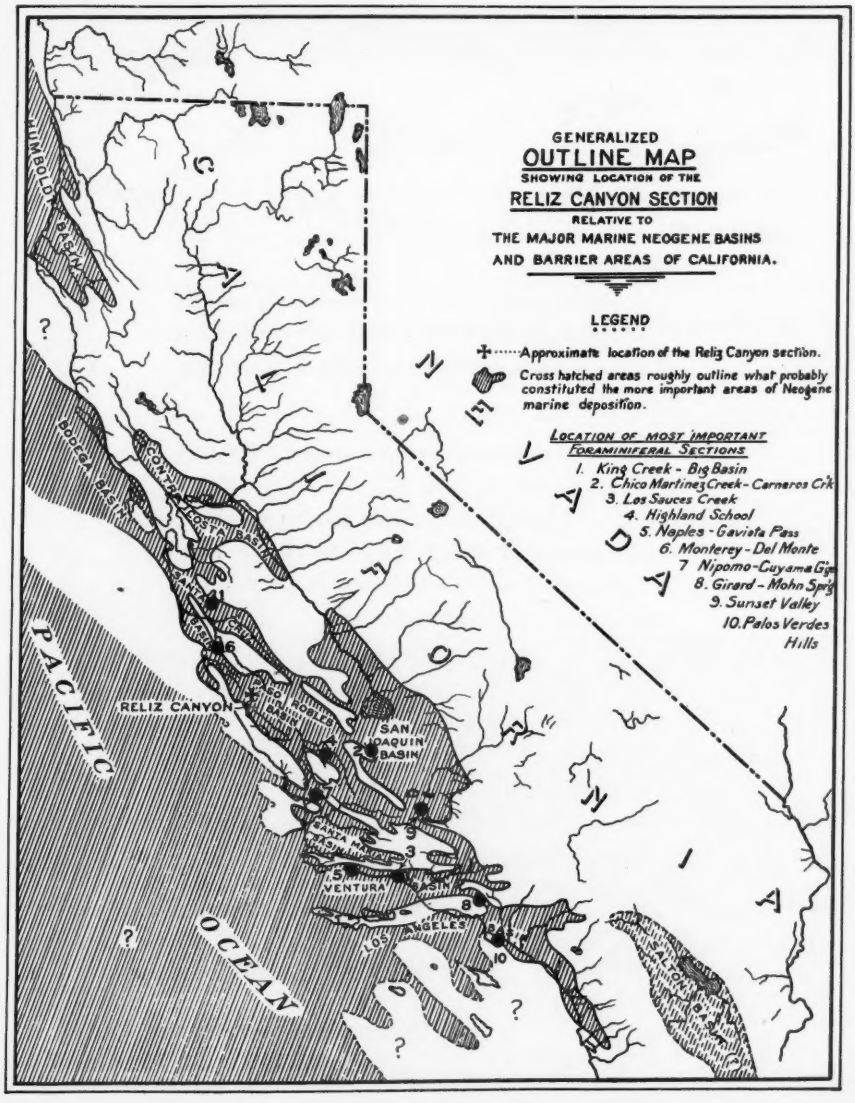

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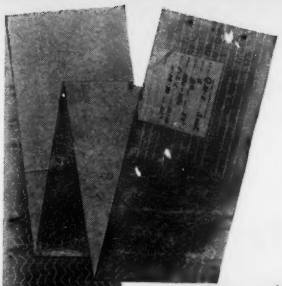

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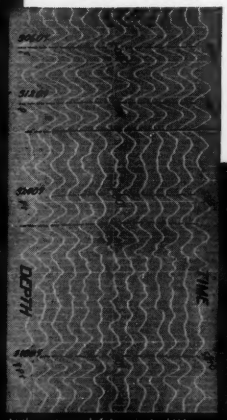

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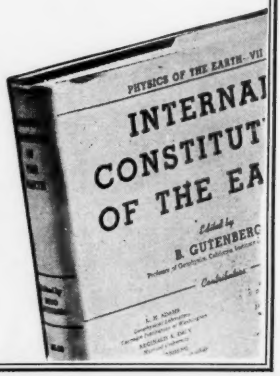

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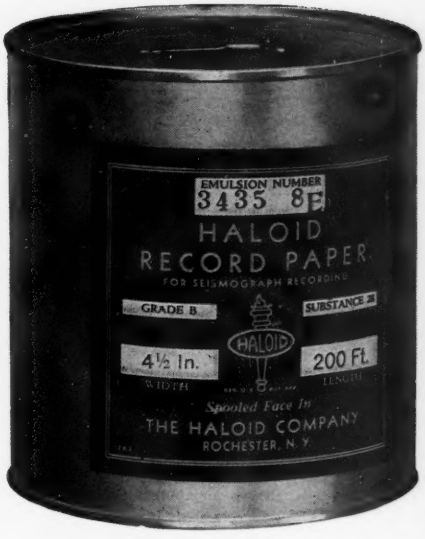

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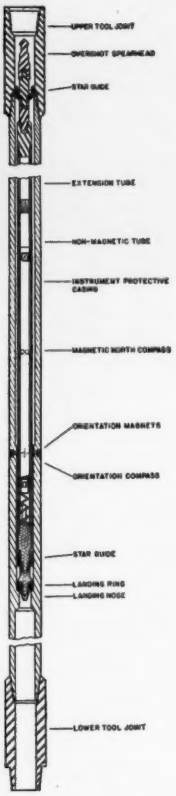

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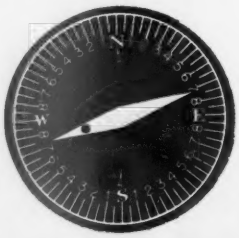

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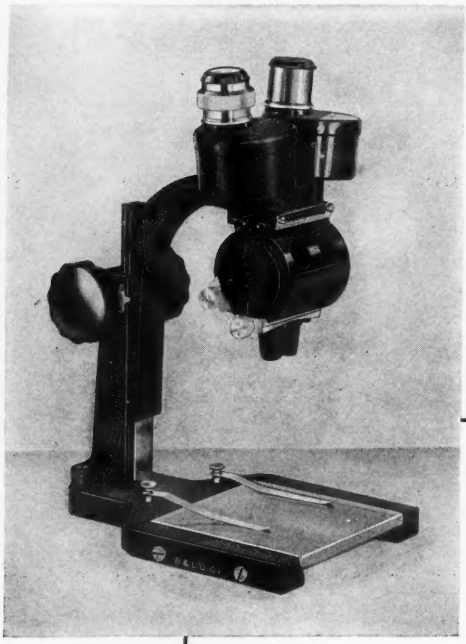

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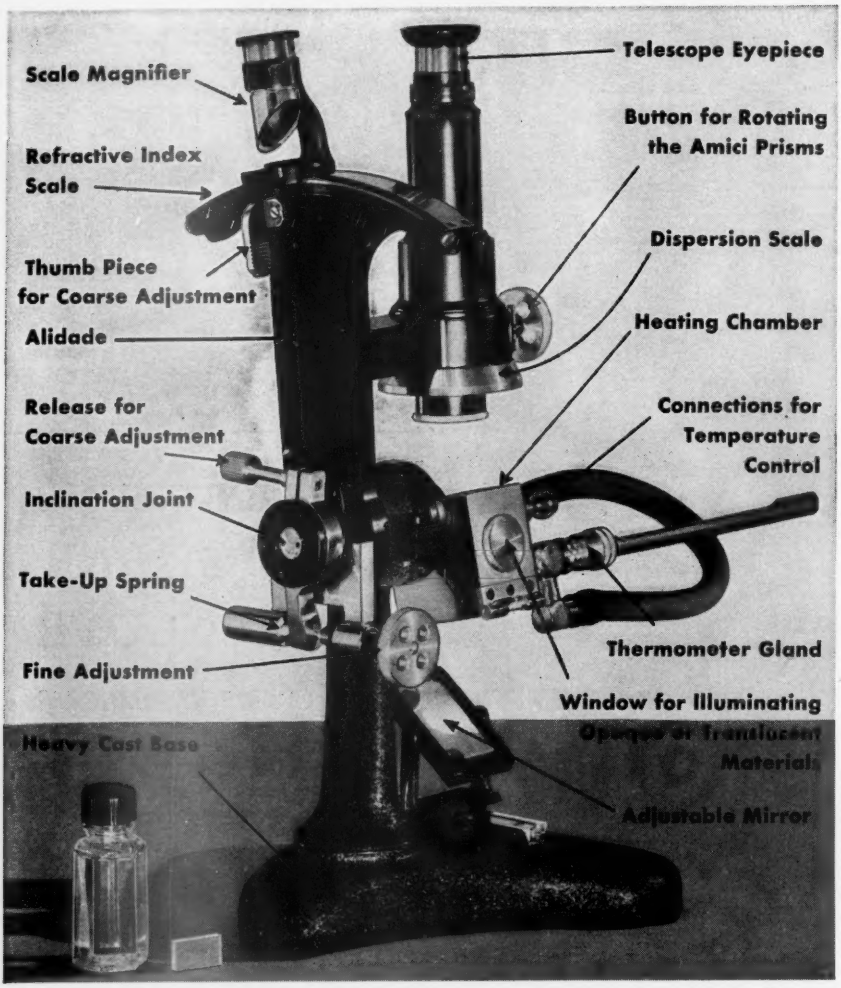

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Recent Field Studies in Osage, Washington, and Nowata Counties, Oklahoma
By MALCOLM C. OAKES

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